3.4 GEOMORPHOLOGY, HYDROLOGY, AND WATER QUALITY

This section describes the geomorphology, hydrology, and water quality conditions in the Yolo Bypass Wildlife Area. It provides an overview of the historical setting, including the principal natural and human-caused changes in the Yolo Basin/Bypass that have occurred over time. It also describes the key physical and chemical conditions of the Yolo Bypass that define the Yolo Bypass Wildlife Area's existing characteristics.

The following text was developed through a review of scientific literature and existing data sources, aerial photography, Yolo Bypass Wildlife Area staff information, and staff expertise. These sources provided information on the historic and existing geomorphic and hydrologic conditions and current water quality conditions in the Yolo Bypass Wildlife Area.

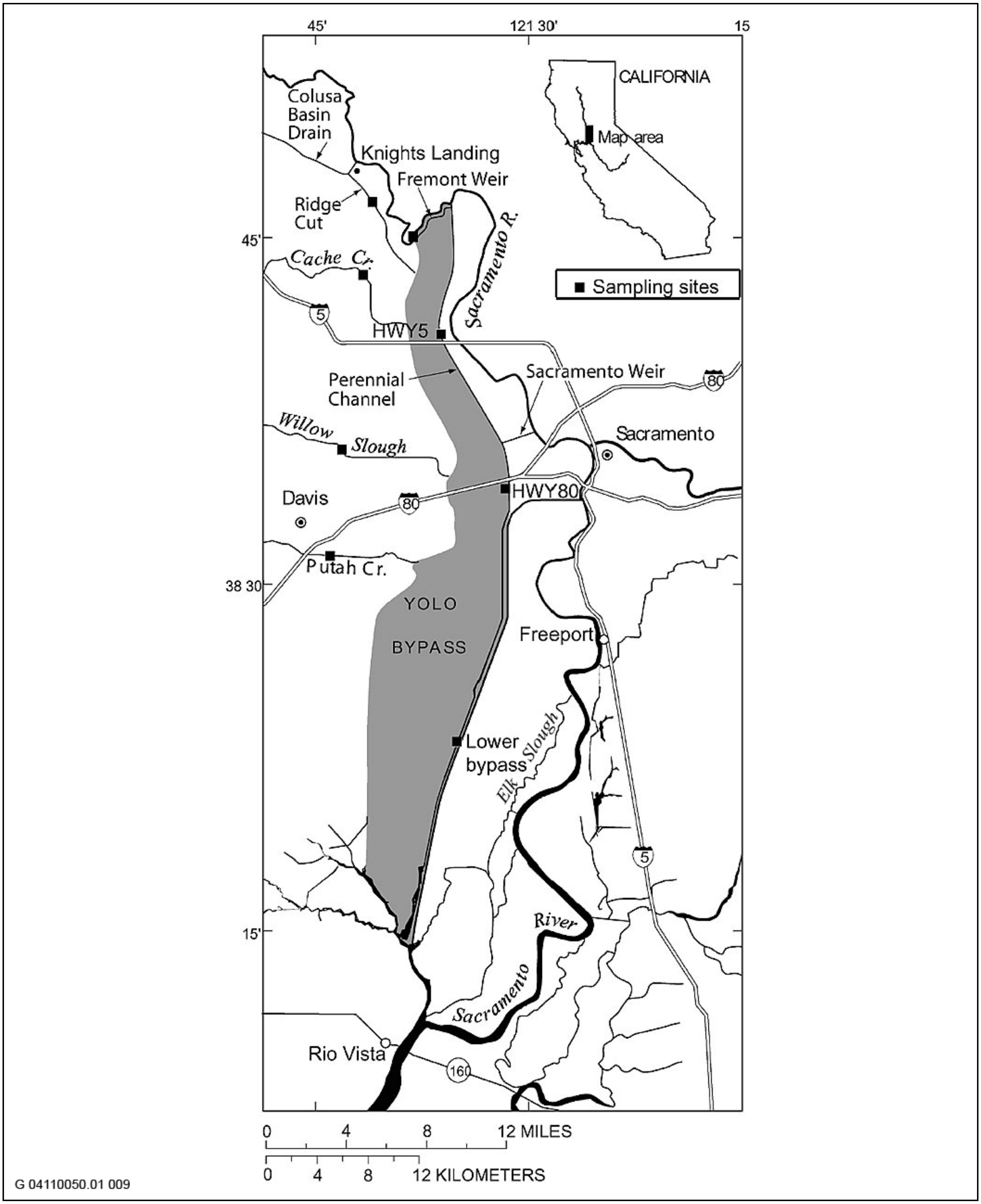
HISTORIC LANDSCAPE

The lower Sacramento River from Knights Landing to the Delta, along with its adjacent flood basins (Yolo Basin to the west and the American Basin to the east) formed a single geomorphic system shaped by tectonic subsidence, flood borne sedimentary processes, and a rising sea level following the end of the last Ice Age 10,000 years ago. The broad natural levees along the river were built up by the deposition of coarser sediments deposited during floods and supported a continuous miles-wide corridor of mixed riparian and valley oak riparian forests in the floodplain meander belt, transitioning to extensive tule marsh extending from the basins to the estuary, as described below. As the river meandered and banks eroded, large overhanging trees along the riverbank would fall into the channel creating structurally complex riverine habitat. This dynamic landscape provided high quality habitat for anadromous fish migrating between the estuary and the upper Sacramento River and for millions of migratory and resident birds and large and small mammals.

Geomorphology

The historic Yolo Basin (Basin) was a natural depression formed on the Sacramento Valley floor after the last Ice Age. It was defined to the north and east by the natural levees of the Sacramento River and its distributary channels, on the west by the edge of the coalesced alluvial fans of Putah Creek and Cache Creek, and to the south by the tidal tule marshes of the Sacramento River Delta (see Exhibit 1-3). The trough of the Basin was about 12 feet lower than the tops of the adjacent natural levees and was isolated from the river except during larger flood events that overtopped the natural levees (Phillip Williams and Associates 2005). The area most susceptible to overtopping was the reach affected by backwater from the Feather River, in the vicinity of the present Fremont Weir, as shown by Exhibit 3.4-1. Although overtopping of the natural levees in this area would occasionally form 'crevasses' that would erode and redistribute sediments, scouring was insufficient to create distributary channels through the Basin. Only where this influence was felt at the vicinity of Freeport (see Exhibit 3.4-1) would permanent crevasses form in the natural levee of the Sacramento River allowing the formation of stable distributary channels like Elk Slough (Exhibit 3.4-1).

The trough of the Basin therefore did not function as a true floodplain that directly interacted with the Sacramento River as it rose and fell during the winter and spring. Instead it formed a vast mosaic of wetlands that transitioned from seasonal wetlands in the north, through willow thickets, tule marshes, and backwater ponds, to the freshwater tidal marshes and slough channels of the estuary to the south. The wetlands were seasonally fed by runoff and groundwater discharges from the Sacramento River and from Putah and Cache creek alluvial fans to the west. The Basin was intermittently inundated by large flood overflows from the Sacramento, Feather, and American rivers and from Putah and Cache creeks. Based on historic maps it appears that permanent wetlands



Source: Schemel 2002

Current Map of Yolo Bypass **Exhibit 3.4-1**

formed in low-lying areas characterized by a high water table. Willow thickets grew around the margins and at the edges of the alluvial fans from about 5 to 10 feet above sea level. An extensive tule marsh occupied the Basin trough below elevations of about 5 feet above sea level, blending into the tidal tule marsh above Cache Slough (Exhibit 1-2) at elevations of about 3 feet above sea level. The non-tidal marsh functioned differently from the tidal portion as it was mapped with no distinct natural drainage channels and probably functioned with lower flows gradually filtering through the vegetation towards the estuary. This type of wetland would tend to accumulate alluvial sediment, gradually rising in elevation, and isolating floodplain ponds on its periphery.

Hydrology

The hydrology of the Sacramento River is dominated by the Mediterranean climate of the region with wet winters, dry summers, and long multi-year periods of extreme wet and drought conditions. The high peaks of the Sierra Nevada intercepted much of the moisture coming off the ocean and stored it as snow and ice that melted gradually, generating cold rivers that flowed throughout the dry summers. During periods of high snowmelt and rainfall, much of the Central Valley became inundated, forming an extensive inland sea that took months to drain downstream to the Bay-Delta system. In moderate flood years, the river frequently overtopped it banks spilling into the Yolo Basin. The Basin likely remained inundated in the southerly portions of the Basin until late spring. During the dry season, river flows were greater than 5,000 cubic feet per second (cfs) (Phillip Williams and Associates 2006).

The Sacramento River historically was the largest watercourse affecting the Yolo Basin from the north and east (Central Valley Habitat Joint Venture 1993). Cache Creek, Putah Creek, and Willow Slough were the major tributaries inflowing to the basin from the west. Flows slowly drained towards the south through a vast array of wetlands and non-tidal marshes into the tidal marshes of the north Delta. Permanent bodies of water persisted in the Cache Creek Sink and Putah Creek Sinks.

Historically, Putah Creek frequently overflowed its banks during high flow events in winter and spring (Central Valley Habitat Joint Venture 1993). Elevated ground water elevations within the Putah Basin contributed to seasonal floods that resulted in a meandering planform (i.e., condition of a stream as seen in aerial view) with a gently sloping alluvial fan that formed as a result of accumulated sedimentary deposits. Along the western edge of the Sacramento floodplain, Putah Creek meandered towards depressions (“sinks”) along the base of the Yolo Basin. This area is currently referred to as the Putah Creek Sinks. Putah Creek historically supplied substantial amounts of water to tule marshes within the Basin. Before construction of the Monticello Dam and the subsequent water regulation, the streams annual discharge into the Basin was approximately 359,000 acre-feet (Central Valley Habitat Joint Venture 1993). During dry flows, the reduced inflows and discharging groundwater resulted in intermittent deep pools within its lower reaches.

The Cache Creek Basin was geologically divided into upper, middle, and lower reaches by Clear Lake, the Vaca Range and the Sacramento Valley floor (Central Valley Habitat Joint Venture 1993). Little is known about the pre-European condition of lower Cache Creek, however, flows probably ranged from very little runoff during the summer months to approximately 40,000 cfs during the winter and spring events (Central Valley Habitat Joint Venture 1993). Historically, the creek transported large amounts of sediment to the valley floor, defining the northern boundary of the Yolo Basin, as its waters disappeared most of the year into the Cache Creek Sink.

Willow Slough has a small watershed and historically consisted of intermittent swales and sloughs which drained to the Yolo Basin between Putah and Cache creeks. The slough was fed by groundwater about four miles north of Putah Creek and terminated several miles southeast of the Cache Creek Sink.

HUMAN CHANGES TO THE LANDSCAPE

Modifications to Geomorphology

Regular flooding in the Sacramento Valley led to the construction of the Sacramento Flood Control Project that converted the natural Yolo Basin into the weir regulated Yolo Bypass. The history of this flood control system is discussed in Section 3.6, "Cultural Resources."

The Bypass is 41 miles long and is surrounded completely on the east and partially on the west by levees constructed by the U.S. Army Corps of Engineers (USACE) (Yolo Basin Foundation 2001). Levee construction began in 1917 and the weirs were completed in 1917 (Sacramento Weir) and 1924 (Fremont Weir). The designs of the levees meet the calculated water-surface profile of the designed flow, with an extra buffer for freeboard. A small segment along the western boundary of the Bypass between Putah Creek and County Road (CR) 155 does not have a constructed levee due the sufficient height of the natural ground elevation.

In 1963, a deep water ship channel was constructed along the eastern edge of the Bypass. The material excavated for this channel was used to construct a second levee along the west side of the channel from the I-80 causeway to the southern tip of Prospect Island. This new levee was higher than the existing flood control levee, and thus serves as the new east levee for the Bypass. The construction of the ship channel decreased the designed conveyance capacity of the Bypass and increased the impacts of smaller flood events (Yolo Basin Foundation 2001).

There are a variety of small interior levees and berms constructed for local agricultural development that partially hinder the flood conveyance of the Bypass. These features have been used to prevent the inundation of particular areas from tidal fluctuations and small floods. The grading of land for such features is controlled by the Reclamation Board. Examples of major interior levees include the north levees of Little Holland Tract and Liberty Island.

In addition, the construction of causeways and bridge crossings along I-80, I-5, portions of the abandoned Sacramento North Railroad (SNRR) and the Southern Pacific Railroad (SPRR) also affected flood conveyance in the Bypass.

The flows in the Bypass produced from the 1986 and 1997 floods roughly equaled the capacity of the Bypass. Analysis of peak flows indicated that both of these floods approximately equaled that of a 70-year event (U.S. Army Corps of Engineers 1991; Yolo Basin Foundation 2001). Water surface elevations during the 1986 flood were only 2 to 3 feet below the crest of the east levee and 2 to 4 feet above the design water surface profile in some locations (U.S. Army Corps of Engineers 1996). In both the 1986 and 1997 floods, areas west of the Bypass along the unleveed section were inundated. As a result of these recent floods, some of the levees have incurred substantial wave damage including slipping and the creation of erosional shelves.

MODIFICATIONS TO HYDROLOGY

Flooding of newly developed agricultural land, aggravated by the cumulative effects of 19th century hydraulic mining led to the implementation of large-scale flood control projects within the entire Sacramento Basin (Central Valley Habitat Joint Venture 1993). In 1911, the State Reclamation Board was assigned to coordinate a basin wide plan for flood control for the entire Sacramento Valley. This project included the construction of a bypass capable of delivering 500,000 cfs of water through Cache Slough in the north delta and increasing the Sacramento River capacity to 100,000 cfs from Sacramento to Cache Slough (Central Valley Habitat Joint Venture 1993). Levees were constructed along both sides of the Yolo Bypass with project completion in 1948. The Yolo Bypass is the largest flood control bypass in California. It prevents flooding of the City of Sacramento and other nearby cities and farmland by diverting floodwaters through the Fremont and Sacramento Weirs and routing them directly to the Sacramento Delta, just north of Rio Vista, as shown by Exhibit 3.4-1 (Schemel et al. 1996).

The Central Valley Project (CVP) (1938) and the State Water Project (SWP) (1951) were also designed as part of the Sacramento Valley Flood Control system (Central Valley Habitat Joint Venture 1993). Their purpose was to improve the imbalance in water supply between the northern and southern parts of the state. This project included 20 reservoirs and 1,100 miles of canals in the Sacramento, Trinity, Feather, American, and San Joaquin river basins. The CVP featured reservoirs created by Shasta Dam on the Sacramento River, Whiskeytown Dam on Clear Creek, and Folsom Dam on the American River. The SWP featured the reservoir at Oroville on the Feather River.

In 1957 the U.S. Bureau of Reclamation constructed Monticello Dam on Putah Creek, located 10 miles upstream of Winters, California. The reservoir (Lake Berryessa) has a capacity of 1.6 million acre-feet, which is approximately four times the average annual runoff of Putah Creek. This large capacity has decreased the 100-year peak flow from 90,000 cfs (pre-dam) to 32,300 cfs (post-dam). The large decrease in peak flows and annual discharge has decreased sediment influx and capacity, essentially dried out the Putah Creek Sinks and prevented additional alluvial fan formation. Since the 1950’s, there has been no significant change in channel alignment downstream of Lake Berryessa (U.S. Army Corps of Engineers and CALFED Bay-Delta Program 2002).

Cache Creek drains approximately 1,290 square miles as it travels nearly 80 miles from its natural outlet from Clear Lake to its confluence with the Yolo Bypass. Flows have been controlled by the Indian Valley Reservoir on the north fork of Cache Creek since 1974 and by the Clear Lake Dam since 1913. Gravel mining, extensive grazing, and naturally erodible soils in the watershed contribute to a high sediment yield with an annual average suspended-sediment load of approximately 1.5 million tons per year (Jones et al 1972). The approximately two square-mile Cache Creek Settling Basin (constructed in 1937) was designed to catch this sediment before it entered the Yolo Bypass. In 1993 the USACE completed a reconstruction of the Settling Basin by enlarging it and removing several million cubic yards of sediment. Before this reconstruction, accumulated sediment had filled the Settling Basin, allowing substantial quantities of sediment to reach the Bypass (Central Valley Habitat Joint Venture 1993).

The Colusa Drain was connected to the Bypass via the artificial overflow channel Knights Landing Ridge Cut (Yolo Basin Foundation 2001). The Drain has a watershed area of 130 square miles, receiving input from all the creeks flowing from the Coast Range between Knights Landing and Stony Creek. The Drain transports drainage and irrigation water nearly 70 miles between Stony Creek and Knights Landing along the west side of the Sacramento River (Exhibit 3-2). The drain released water to the Sacramento River from a set of gates (constructed 1930) that maintain a constant upstream (drain side) water elevation of 25 feet (0 ft USACE datum = -3 ft MSL). The design allows for a backwater condition along the entire length of Knights Landing Ridge Cut which facilitates water for irrigation. To prevent water from flowing into the Bypass, a berm is constructed at the Bypass end of Knights Landing Ridge Cut. Flows entering the Sacramento River through the Colusa Basin Drain are measured by the DWR. When flows on the Sacramento River increase to 25 feet, the Colusa Drain closes and flows move through the Knights Landing Ridge Cut to the Bypass. These flows are not gaged but DWR does operate a second gage about halfway down the Drain where it crosses Highway 20.

3.4.1 EXISTING GEOMORPHOLOGY

SEDIMENT INPUT INTO THE YOLO BYPASS

Wright (2004) studied the changing trends of sediment yield within the Sacramento Basin for the period from 1957 to 2001. By examining the discharge and sediment yields on the Sacramento River upstream and downstream of the Fremont and Sacramento Weirs, which allow sediments to enter the Yolo Bypass, he was able to make the following conclusions:

- There is a very high probability of a decreasing trend in suspended-sediment discharge for a given flow.
- The annual suspended sediment yield has decreased by one-half from 1957 to 2001.
- During the largest flood events, peak sediment concentrations have decreased with time.
- The three largest reservoirs in the watershed have accumulated a mass of sediment of the same order of magnitude as the decreases in suspended-sediment yield from 1957 to 2001.

It has been suggested that this decreasing trend in suspended-sediment discharge is a result of reservoir sedimentation, bank protection measures, and the gradual depletion of stored hydraulic mining sediments. Although the data used to make these conclusions have been derived from the main stem of the Sacramento River; it is reasonable to suggest that the same trends will hold for sediment input into the Yolo Bypass through the Fremont and Sacramento Weirs.

If the balance between sediment supply and transport capacity has reached equilibrium, there should be a minimal change in sediment input into the Bypass in the future. However, changes in factors such as logging, levees, urbanization, and agricultural practices can have the potential to increase future sediment yield (Wright 2004).

3.4.2 EXISTING HYDROLOGY

SURFACE WATER HYDROLOGY

Current Operation of the Yolo Bypass

The Yolo Bypass provides a direct path from the confluence of the Sacramento and Feather Rivers and the Sutter Bypass to the Sacramento River Delta. Flow is diverted from the Sacramento River into the Bypass when the stage exceeds 33.5 feet (corresponding to 56,000 cfs at Verona). Diversion of the majority of Sacramento River, Sutter Bypass, and Feather River floodwaters to the Yolo Bypass from Fremont Weir controls Sacramento River flood stages at Verona. During large flood events, 80% of the Sacramento River flows are diverted into the Bypass. The Sacramento River at the Fremont Weir has natural levees on the unprotected right (south) bank, and out of bank flows disperse through a series of tree covered areas of higher ground dissected by distributary channels until reaching the upper end of the Fremont Weir. The high ground and distributary channels regularly shown on old maps of the area are considered natural apart from being maintained through the periodic removal of sand deposits by DWR.

The area between the Fremont Weir and the Sacramento River is one of high sediment deposition, as fast moving water from upstream meets slower moving water in the Yolo Bypass. Once water overtops the Sacramento River levees and the Fremont Weir, it flows into the Bypass. In high flow years, additional water can enter the Bypass via the Sacramento Weir. This weir is controlled so that flow can be released once the Sacramento River stage at Sacramento's I Street Bridge reaches 27.5 feet (corresponding to 98,000 cfs). Because the design flood capacity of the American River (115,000 cfs) is 5,000 cfs higher than that of the Sacramento River channel past downtown Sacramento, the Sacramento Weir is a critical component of the project to keep flood control project runoff at safe water levels. The Sacramento Weir and Yolo Bypass are designed and managed to divert an equivalent volume of water from the Sacramento River as that joining it downstream from the American River, to maintain equal flood levels either side of the American River confluence. In practice, during large flood events, approximately 15% of the flow from the American River can pass upstream on the Sacramento River and enters the Sacramento Bypass (California Department of Water Resources 2003).

The weir gates are closed as rapidly as practicable once the stage at the weir drops below 25 feet. This provides “flushing” flows to re-suspend sediment deposited in the Sacramento River between the Sacramento Weir and the American River during the low velocity flow periods in that reach when the weir is open during the peak of the flood event (California Department of Water Resources 2003).

Once water has entered the Bypass it accumulates in the lower eastern side in the area occupied by the Tule Canal (from one mile south of the Fremont Weir to I-80) and the Toe Drain (from I-80 to Liberty Island). These constructed channels lie adjacent to the flood levees on the eastern boundary of the Bypass and collect water from the west side tributaries, primarily Knights Landing, Cache Creek and Putah Creek (Exhibit 3.4-2 depicts natural color bands from tributaries into the flooded Yolo Bypass). Water leaves the Yolo Bypass either via the Toe Drain or Liberty Cut at Prospect Slough via Shag Slough or over the southern end of Liberty Island to Cache Slough.

Flood Hydraulics of the Yolo Bypass

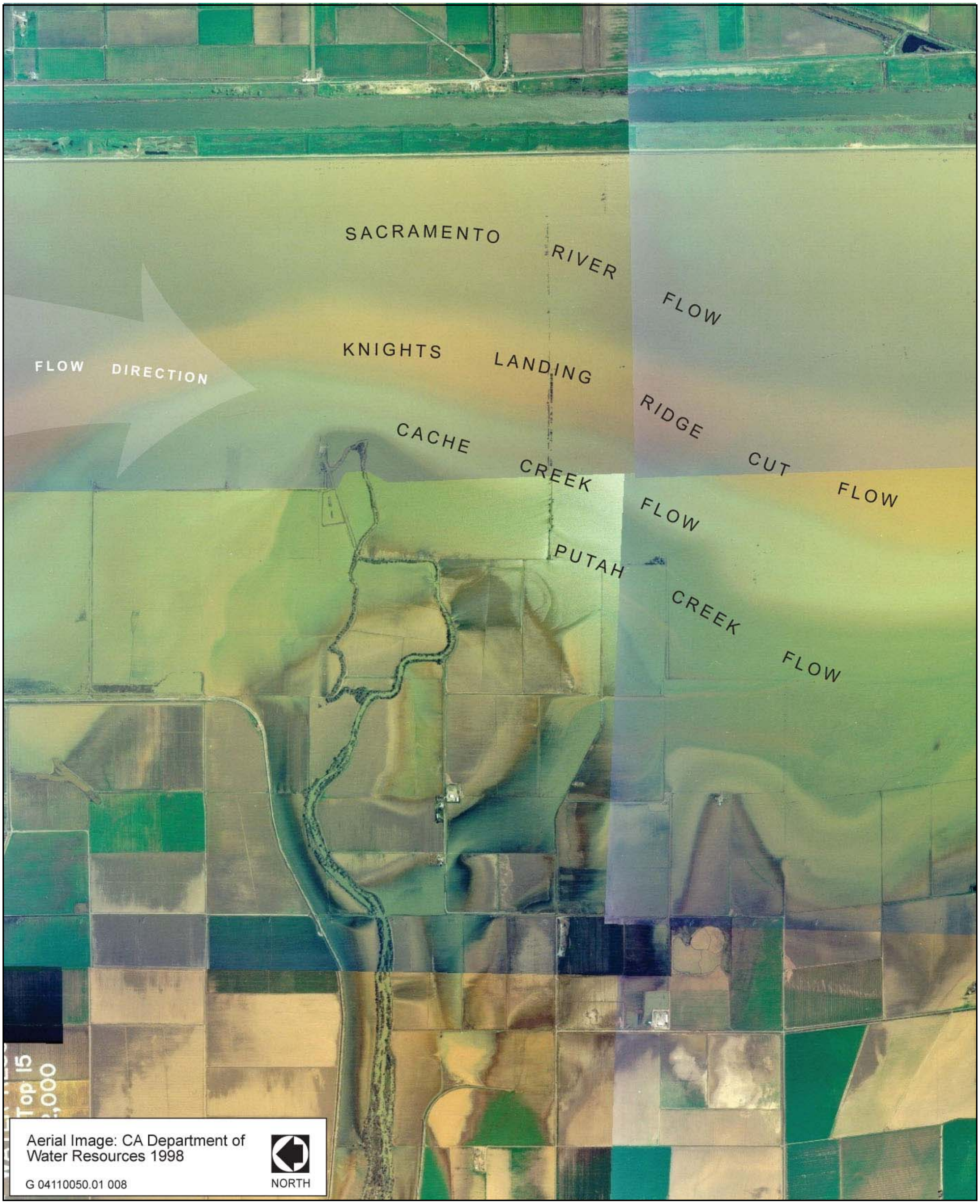
As part of the Sacramento River Flood Control Project, the flood conveyance of the Bypass has been defined for the 100-year flood event. By default, the design water surface profile is the standard by which any future land use modifications within the Bypass, to include those in the Yolo Bypass Wildlife Area, will be judged (U.S. Army Corps of Engineers 2003). The USACE is in the process of finalizing a two-dimensional hydraulic model (RMA2) of the Bypass for the purpose of assessing the impacts of proposed land use changes, such as ecosystem restoration within the Yolo Bypass Wildlife Area, on flood conveyance as well as cumulative impacts on flood conveyance (U.S. Army Corps of Engineers 2006). Typical Manning’s n values and designs flows for future modeling of the Bypass are provided below. Manning’s n values are relative values representative of roughness (resistance to the flow of water) in a channel due to vegetation or other features and are used to calculate measures of flow in rivers and creeks in terms such as velocity and river stage (elevation).

Table 3.4-1 displays the typical roughness conditions or Manning’s n values representative of each land use during the mid-to-late winter flood season within the Bypass. These values were developed based on engineering judgment and model calibration (January 1997 flood) during the USACE’s development of the hydraulic model of the Bypass (U.S. Army Corps of Engineers 2006). Roughness is also affected by the configuration patterns of vegetation. Trees grown in a linear fashion in line with predominant flows present less resistance than a line of trees grown perpendicular to the flow of flood waters.

Table 3.4-1
Land Uses and Flood Season Manning’s n Values

Land Use	Manning’s n Value
Open water	0.025
Fallow agricultural fields	0.030
Pasture	0.040
Native grass	0.045
Maintained levee slope	0.040
Tules	0.045
Mixed grassland/riparian	0.070
Riparian	0.085
Dense riparian	0.120
Bridge crossing	0.070

Source: U.S. Army Corps of Engineers 2006



Source: DWR 1998

Yolo Bypass Natural Color Bands **Exhibit 3.4-2**

Table 3.4-2 displays the boundary conditions for the hydraulic model during the design flood. Tributary inflows were computed by the USACE as the difference between the Bypass design flows upstream and downstream of a given tributary.

Table 3.4-2
Yolo Bypass Boundary Conditions

Inflow Boundary	Discharge (cfs)
Fremont Weir	343,000
Knights Landing Ridge Cut	19,000
Cache Creek (Settling Basin)	15,000
Sacramento Weir	100,000
Willow Slough Bypass	3,000

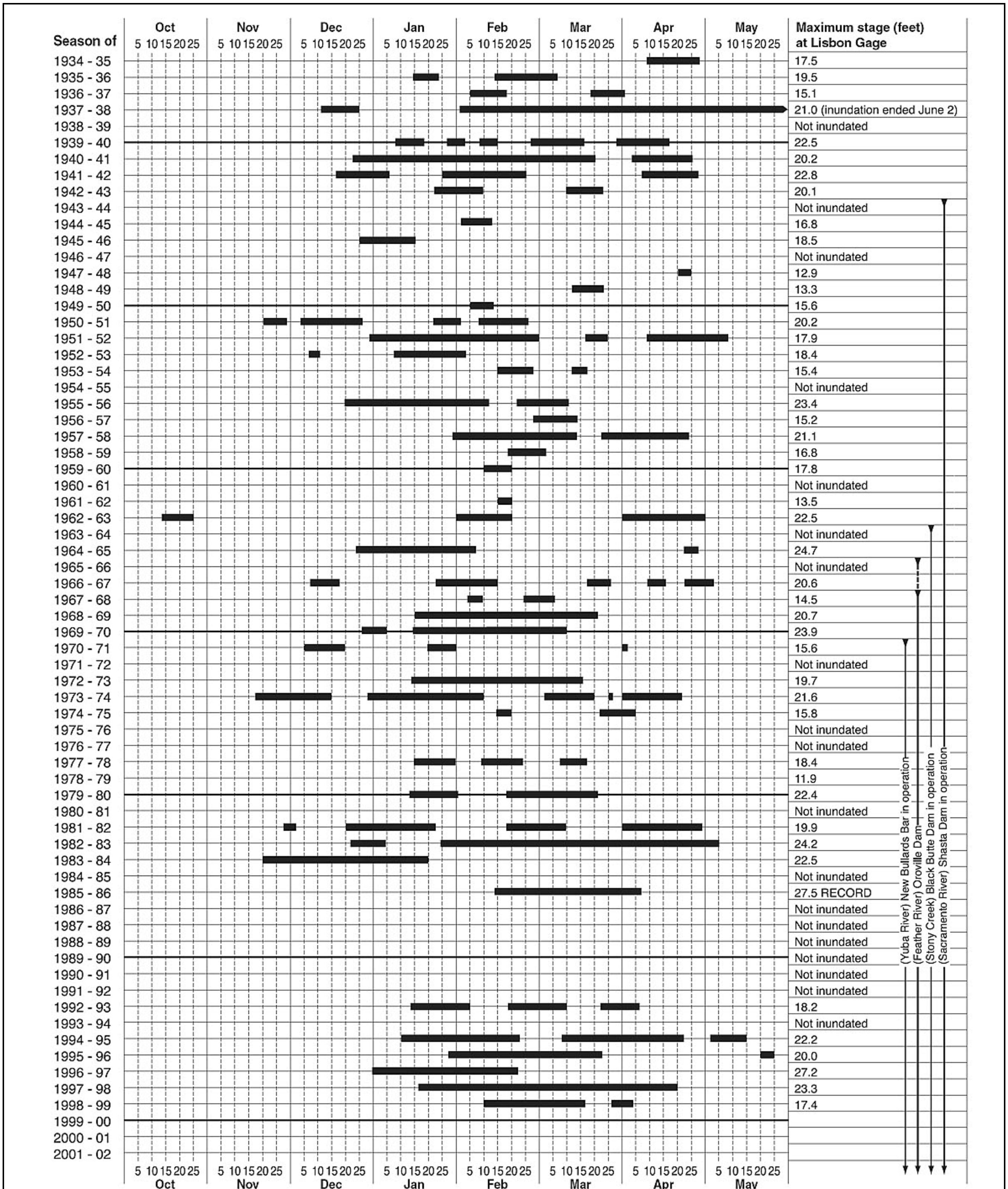
Source: U.S. Army Corps of Engineers 2006

Flood Inundation of the Yolo Bypass

In an effort to quantify the historical frequency, depth, and duration of inundation in the Bypass, stage data was analyzed from the Lisbon Weir. The Lisbon Weir is located in the Toe Drain in the southern section of the Bypass and DWR has recorded stage here since 1935. The stage at the gage site is tidally dominated and oscillates between 3–7 feet USACE (USACE datum). Flood flows entering the Bypass are initially contained within a small perennial channel at the northern end (that becomes the East Toe Drain further to the south), but begins to inundate the floodplain when the discharge exceeds 3,530 cfs or 11.5 feet (USACE datum). Exhibit 3.4-3 displays the times when the stage at Lisbon exceeded 11.5 feet during water years 1935–1999. Inundation occurred in 71% of the years and was uniformly distributed throughout this period. It should be noted that the record number of consecutive years with and without inundation, six years each, both occurred during the period from 1985–1999, which may indicate increased variability in flood hydrology during the recent period.

Exhibit 3.4-3a displays the duration of inundation for each water year from 1935–1999. The seasonal duration of inundation for this period varied from 0 to 135 days. Exhibit 3.4-3a also displays the maximum stage recorded for each year at the Lisbon gage. The stage during the February 1986 and January 1997 floods were both 2.5 feet higher than any other year on record. Exhibit 3.4-4 displays a correlation in the relationship between maximum stage and duration of inundation for the smaller floods during this period. This correlation shows that the higher the stage produced for a given small flood event, the longer the Bypass will be inundated. It is important to note that, in an effort to avoid exceeding the design stage, releases from reservoirs during major floods are typically controlled by increased duration rather than an increased release rate (Yolo Basin Foundation 2001).

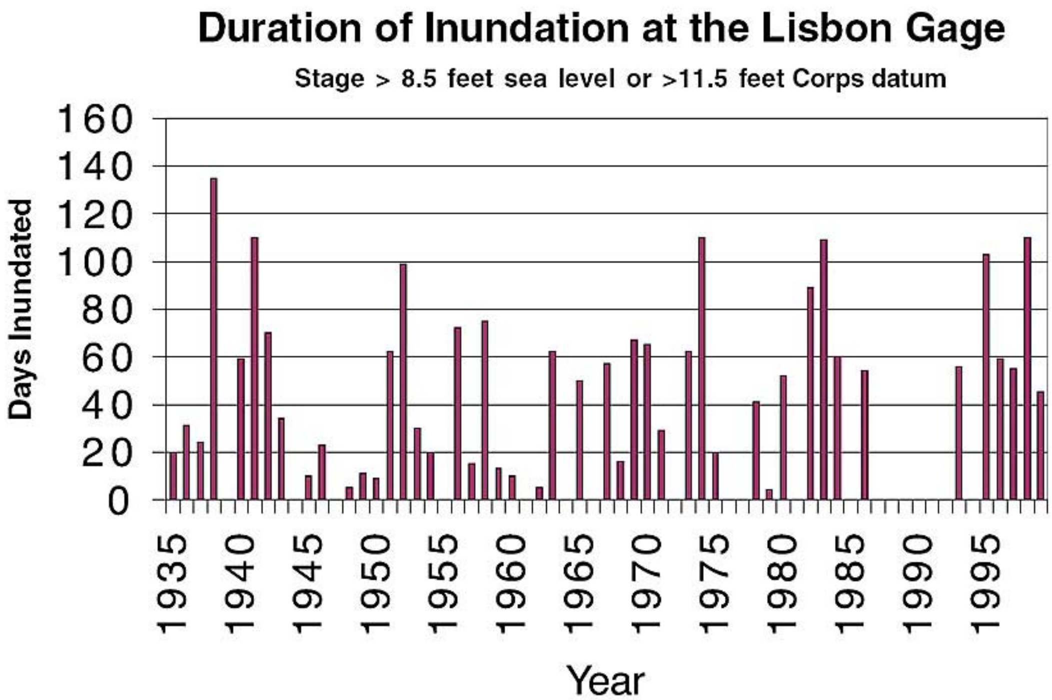
The timing of inundation is of utmost importance to agricultural interests within the Bypass. Inundation in late spring or early fall, although very rare, can have disastrous impacts on unharvested or newly planted crops. Additionally, flooding during this period may trigger the production of tremendous numbers of mosquitoes.
In late spring, inundation occurred after May 10th in only four years between 1935 and 1999 with three of the four occurring since 1990. This recent change has led some to suggest that changes in climate, hydrology or reservoir operations have occurred. The spring floods of 1998 produced the latest (June 10, 1998) and longest duration of inundation. This late spring flood caused substantial economic losses to farmers in the Bypass.
Early fall floods are extremely rare in the period of record, having occurred only once (October 14, 1962) prior to November 18.

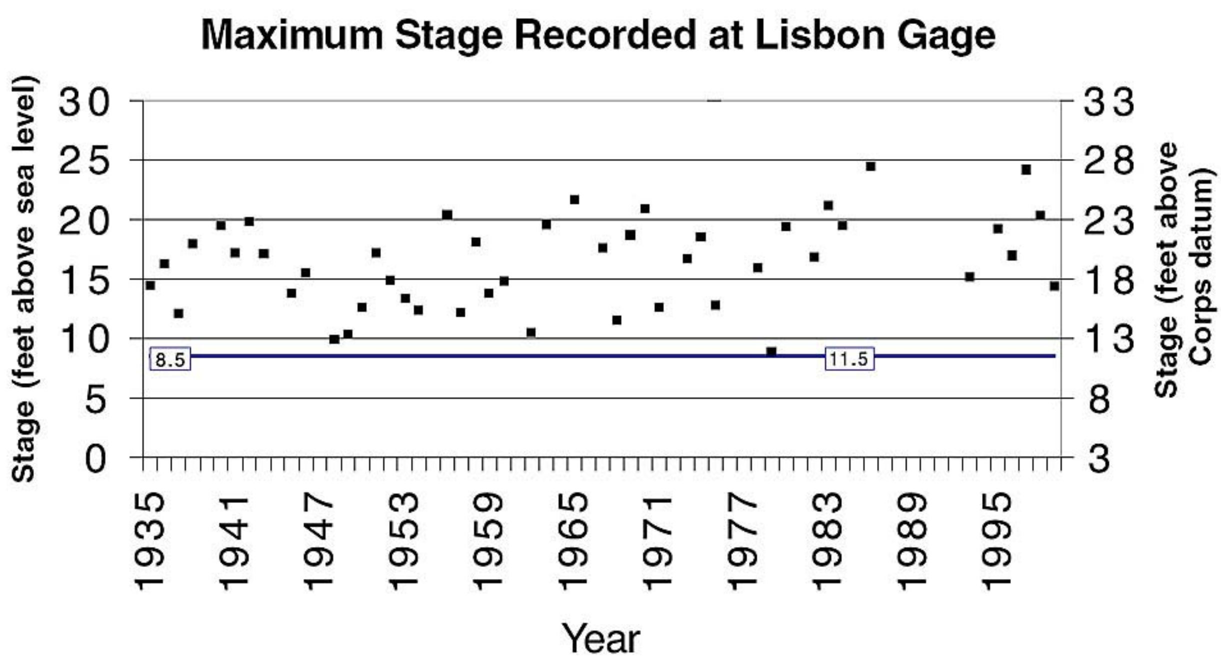


Data compiled from records of DWR stream gaging station "Yolo Bypass near Lisbon". Datum: 0 = 0 feet U.S.E.D. Period of record: 1914-present. Assumed overflow of Bypass at stage above 11.5' on the Lisbon gage. Source: State of California, Department of Water Resources.

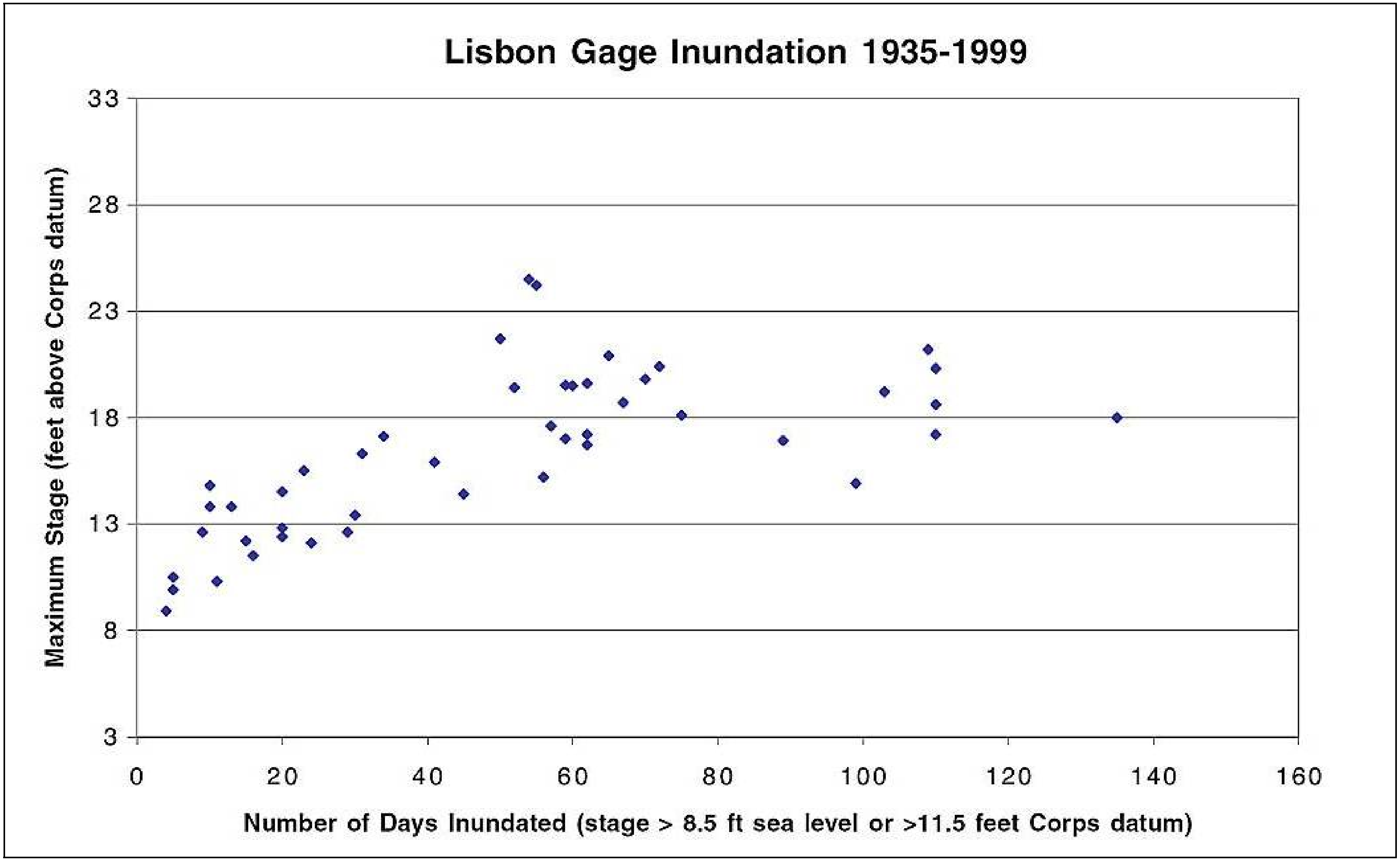
Source: Yolo Basin Foundation 2001

Periods of Inundation at Lisbon Weir **Exhibit 3.4-3**





Duration of Inundation and Maximum Stage at the Lisbon Gage **Exhibit 3.4-3a**



Source: Yolo Basin Foundation 2001

Lisbon Gage Inundation 1935–1999 **Exhibit 3.4-4**

Recent Changes in Flood Inundation of the Yolo Bypass

The 15-year period from 1985 and 1999 has been marked by several record breaking hydrological events (Yolo Basin Foundation 2001). These include two record breaking floods and a record number of consecutive years with and without inundation. Due to these most recent events, many have hypothesized that flood operations have changed, climate has changed, or urbanization has substantially altered runoff. In an effort to determine whether the suspected changes have occurred, historic time series of peak flows, annual discharge, and inundation duration were examined. A linear regression analysis was performed on (duration and stage) (Exhibit 3.4-3a). Neither data set revealed a relationship confirming these changes have taken place.

An analysis of the "four rivers index," which combines hydrologic data for the Sacramento, American, Yuba, and Feather River systems to establish an annual indicator of water availability in the Sacramento Basin, was used to determine if climate change was responsible for the recent extreme hydrologic trends (Yolo Basin Foundation 2001). This analysis involves the correction of flows on the Sacramento, American, Yuba, and Feather rivers to account for changes in storage, diversion, and evaporation in reservoirs. Exhibit 3.4-5 displays the corrected runoff for the 1906–1999 water years. No long term trends were observed, but statistical analysis revealed that runoff variability has been greater in the last 30 years than the 30 years preceding (Dettinger et al. 1995).

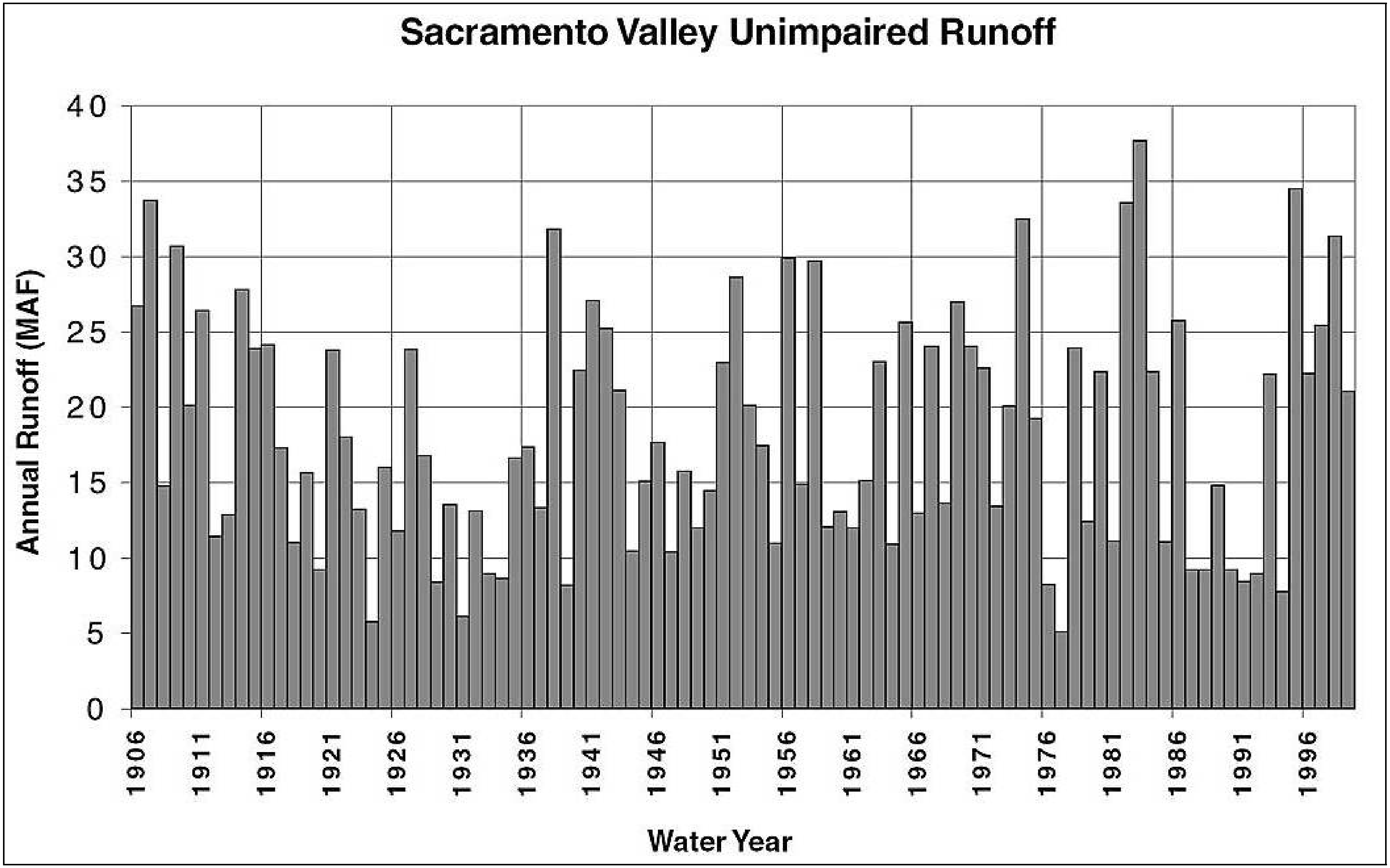
In an effort to examine the potential change in reservoir operations, the relationship between unimpaired runoff and the duration of inundation is plotted in Exhibit 3.4-6. The results of this graph show that the same relationship exists for the recent period as does for the years prior. If there were significant changes in reservoir operations, the trends would have likely changed over the period of record.

Folsom Reservoir has undergone considerable changes in its flood operations since the 1986 flood. After the 1986 flood, it was decided to increase the storage volume from 400,000 acre-feet to a variable volume up to 670,000 acre-feet (Yolo Basin Foundation 2001). During major floods, this increased capacity has lessened the peak flows and thus decreased the stage in the Bypass during those flood events. During medium flood events, the additional capacity in Folsom has allowed for an overall decrease in the combined peak flows released from all reservoirs. Overall, the results of these and other analyses indicate that flood management has not changed from 1985 to 1999.

Low Flow Inundation

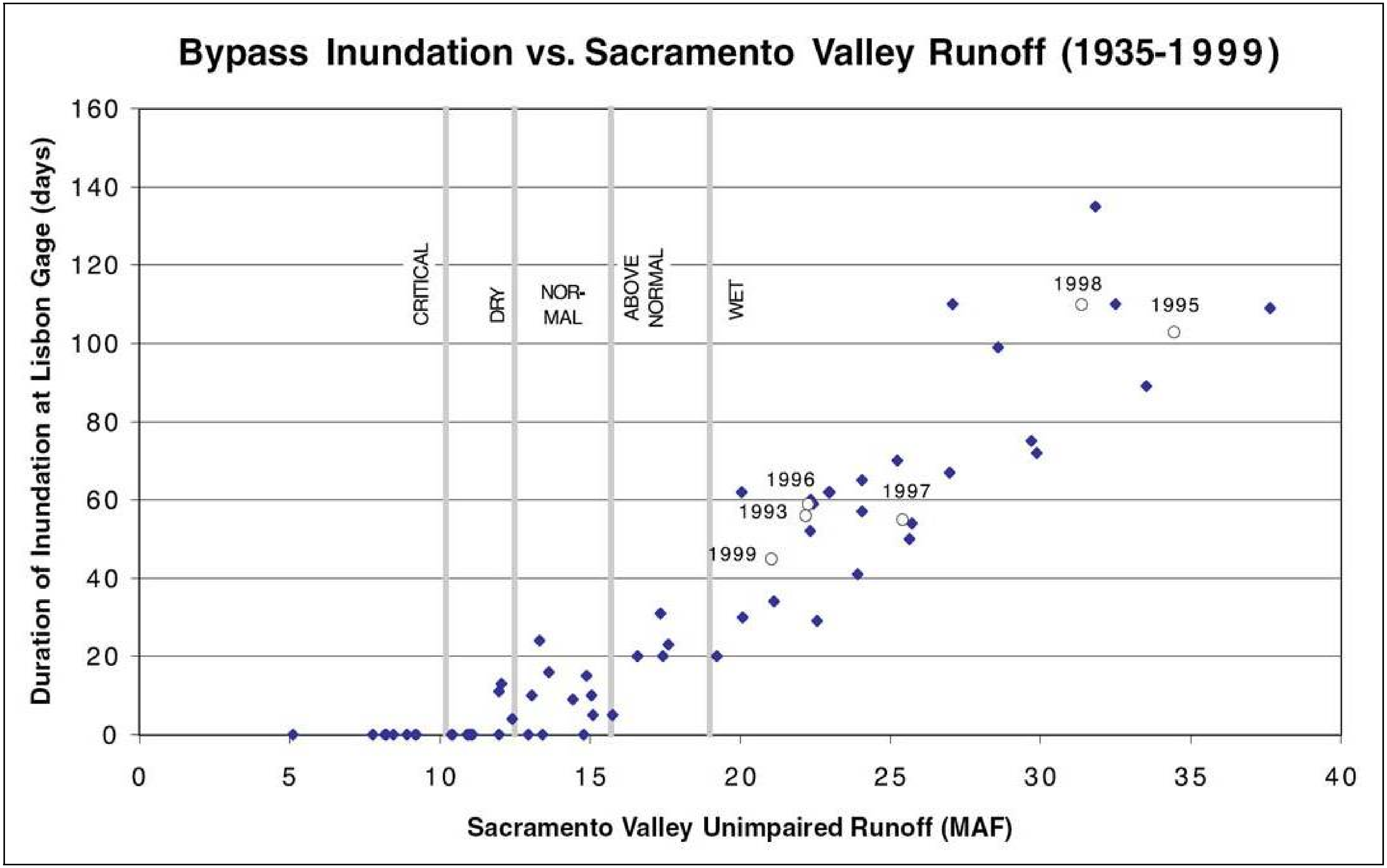
The major inputs to the Bypass are the Fremont and Sacramento Weirs, Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. By comparing the magnitude and timing of the inundation in the Bypass at Lisbon Weir with the magnitude and timing of these inputs, the relative significance of each input for inundation potential can be identified. Exhibits 3.4-7 and 3.4-8 compare the maximum daily flows at the Sacramento and Fremont Weirs, Putah Creek, and Cache Creek to the inundation at Lisbon Weir for each water year from 1935 to 1999. Inundation at the Lisbon Weir showed a strong relationship with the years the Fremont Weir was active and there is also a relationship between the duration of the inundation and the magnitude of the weir flow. Flows through the Sacramento Weir were of a lesser magnitude, although there was a significant relationship between inundation at Lisbon and weir activity.

The timing of the Fremont Weir activity provides further evidence of its pivotal role in inundation of the Bypass. Exhibit 3.4-9 plots the periods of activity of the Fremont Weir from 1935 to 1999. A comparison of this chart to the equivalent chart of inundation events at the Lisbon Weir (Exhibit 3.4-3) reveals a direct correlation between Fremont Weir activity and Bypass inundation. There is a lag of approximately two days from the initial weir activity to inundation, and inundation may lag 5–10 days after weir activity ceases. Very short periods of weir activity do not necessary result in inundation at the Lisbon Weir.



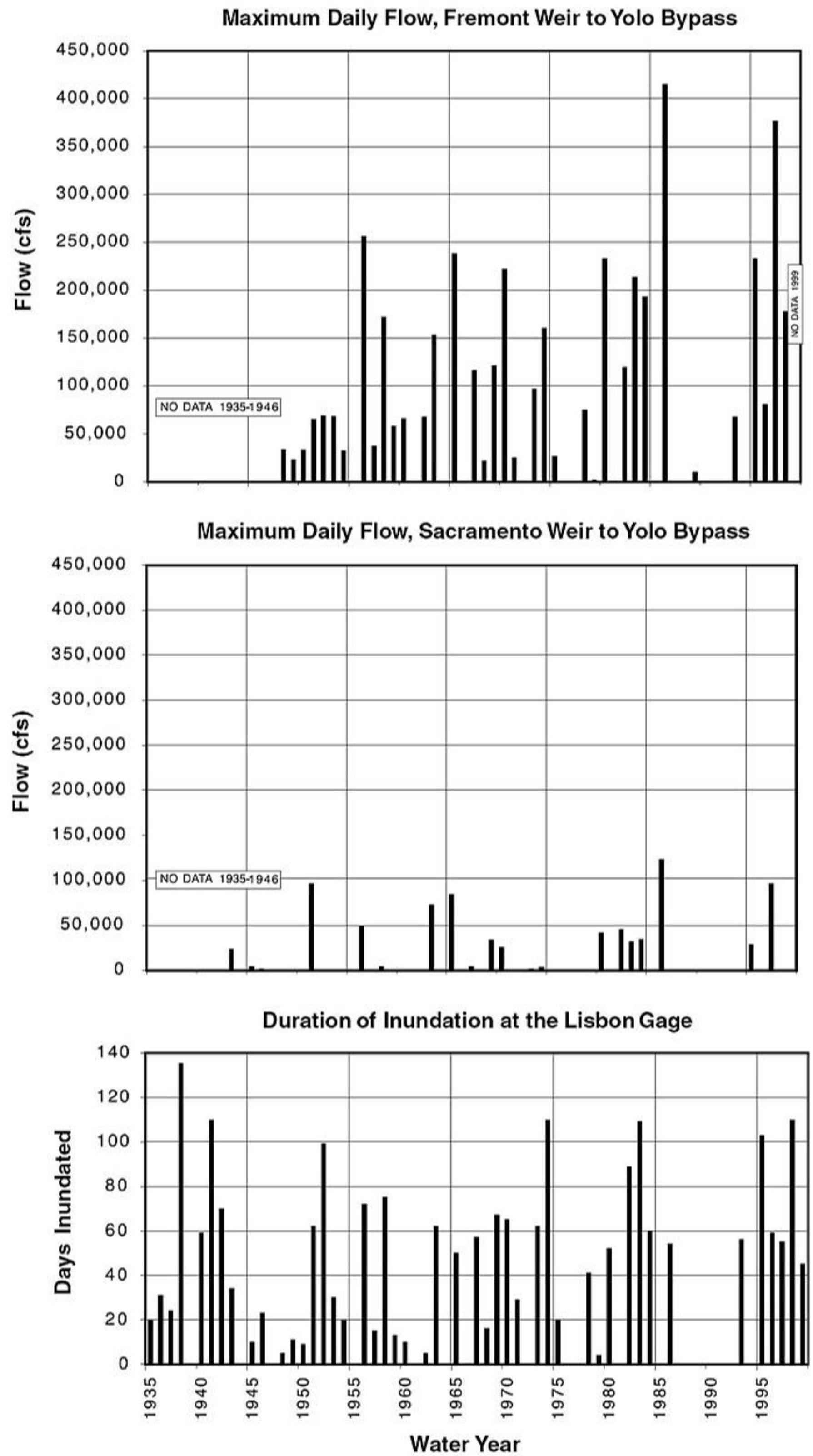
Source: Yolo Basin Foundation 2001

Annual Unimpaired Runoff – Four Rivers Index 1906–1999 **Exhibit 3.4-5**



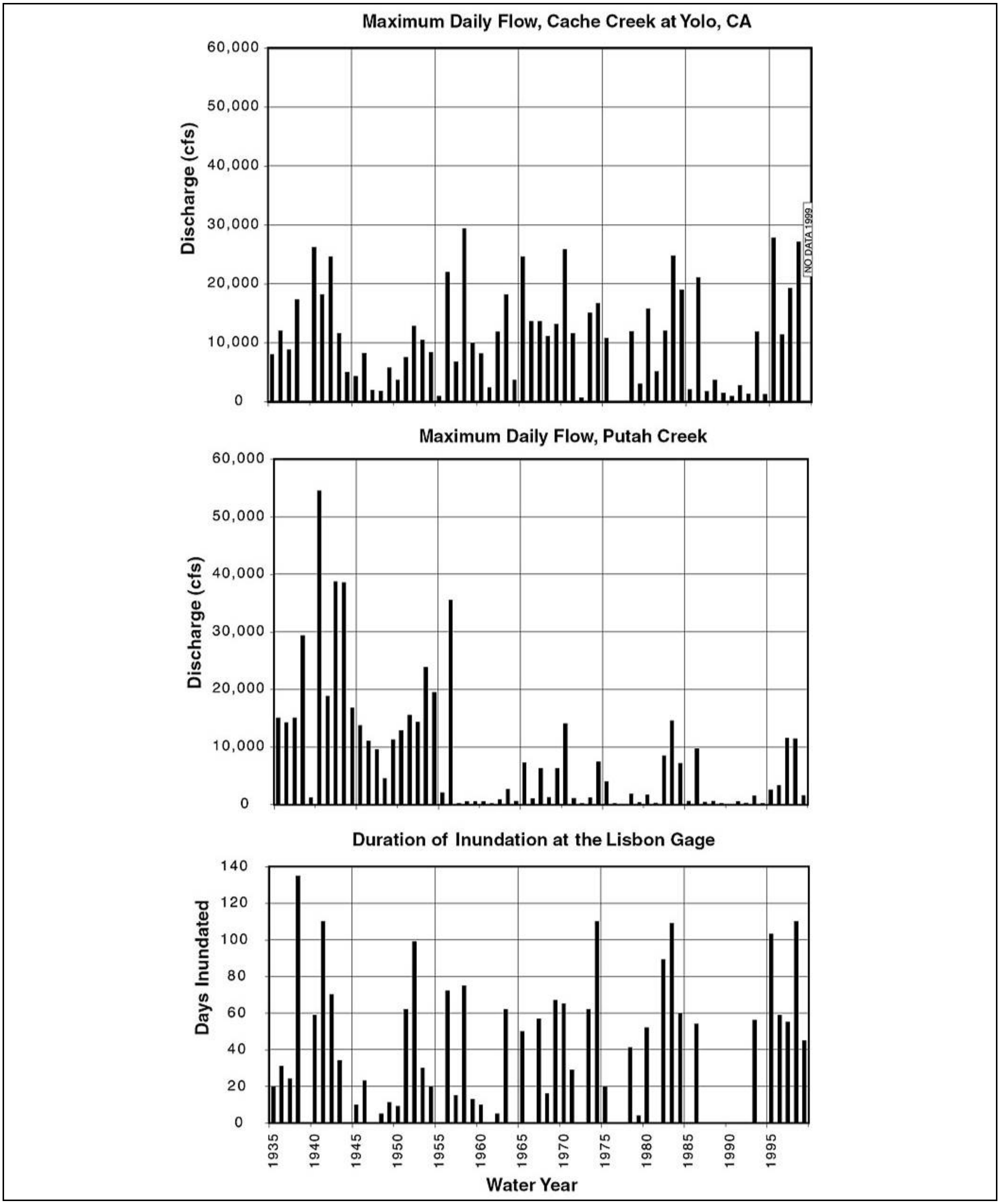
Source: Yolo Basin Foundation 2001
Note: Relationship between Yolo Bypass inundation and Sacramento Valley unimpaired runoff, 1935–1999

Bypass Inundation vs. Sacramento Valley Runoff 1935–1999 **Exhibit 3.4-6**



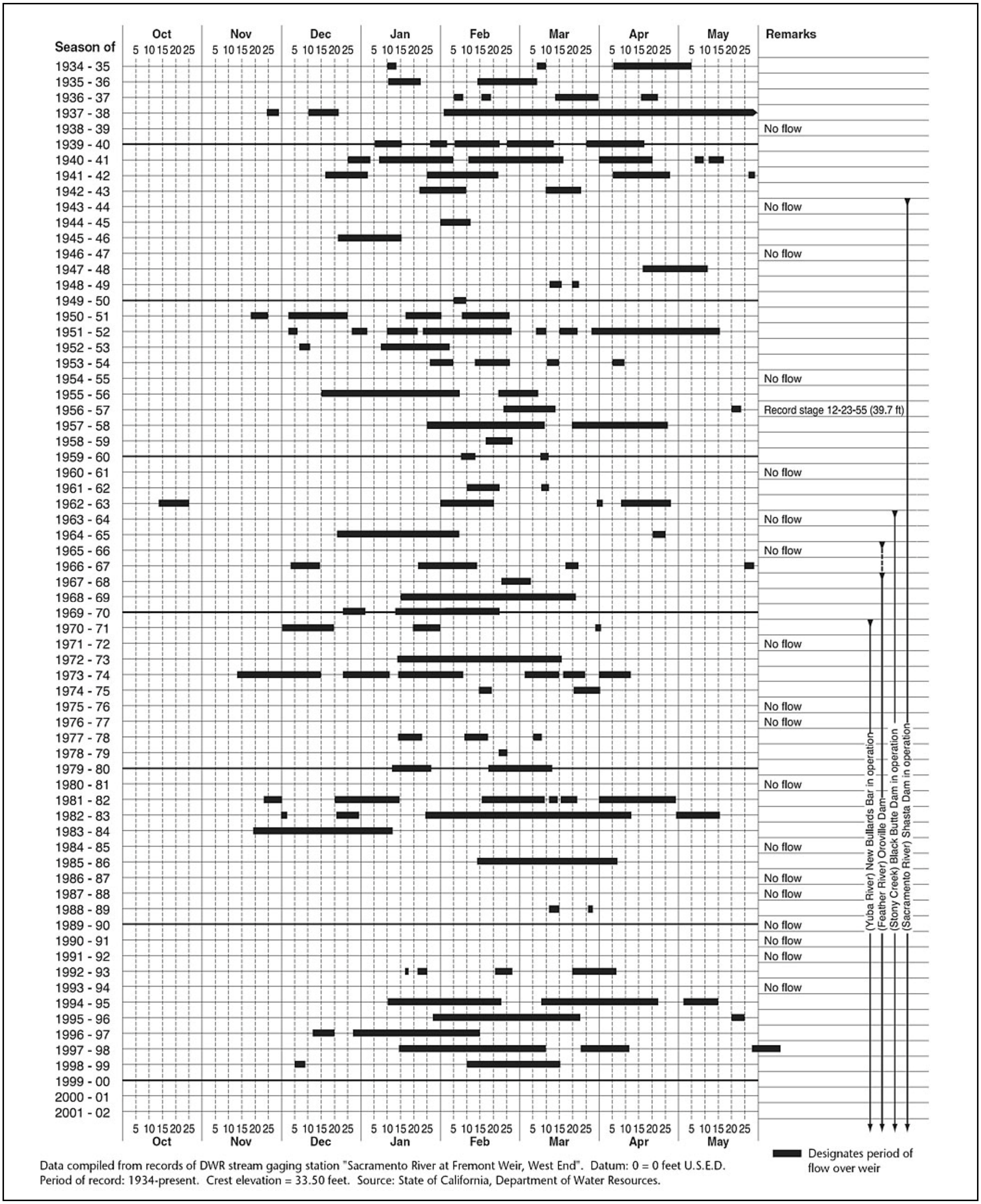
Source: Yolo Basin Foundation 2001
Note: Annual maximum daily flow at Fremont and Sacramento Weirs and duration of Yolo Bypass inundation during water years 1935–1999

Fremont and Sacramento Weir Maximum Daily Flow and Yolo Bypass Inundation 1935-1999 **Exhibit 3.4-7**



Source: Yolo Basin Foundation 2001
Notes: Annual maximum daily flow at Putah and Cache Creeks and duration of Yolo Bypass inundation during water years 1935–1999

Putah and Cache Creeks Maximum Daily Flow and Yolo Bypass Inundation 1935–1999 Exhibit 3.4-8



Source: Yolo Basin Foundation 2001

Periods of Fremont Weir Activity **Exhibit 3.4-9**

Daily flow hydrographs can be useful in identifying the relative contributions of the six sources of inflow to the Bypass. Inflows from Cache Creek, Fremont and Sacramento Weirs are gauged, and the data can be used without adjustment. Yolo Basin Foundation (2001) developed daily flow time series for ungaged sites and sites with missing data by estimating inflow using a variety of methods involving subtraction or addition of flows at upstream gages, watershed runoff correlations based on rainfall and drainage areas, and adjustments for seepage losses. Additional detail on these methodologies can be found in the Yolo Basin Foundation 2001 report. Selected results are summarized below.

Exhibit 3.4-10 shows hydrographs of daily flows during a moderately wet period from 1995 to 1998. Flows from the Fremont and Sacramento Weirs, Knights Landing, Cache Creek, Willow Slough, Putah Creek and the Bypass flow at I-5 are shown consecutively in the top four hydrographs with the hourly stage at Lisbon shown at the bottom. The Y axis scales are 12 times larger for the I-5 and Bypass flows than for the other tributaries. The smaller floods and low flows for this same period can be viewed more easily in Exhibit 3.4-11 with the Y axis expanded 10 times (Yolo Basin Foundation 2001).

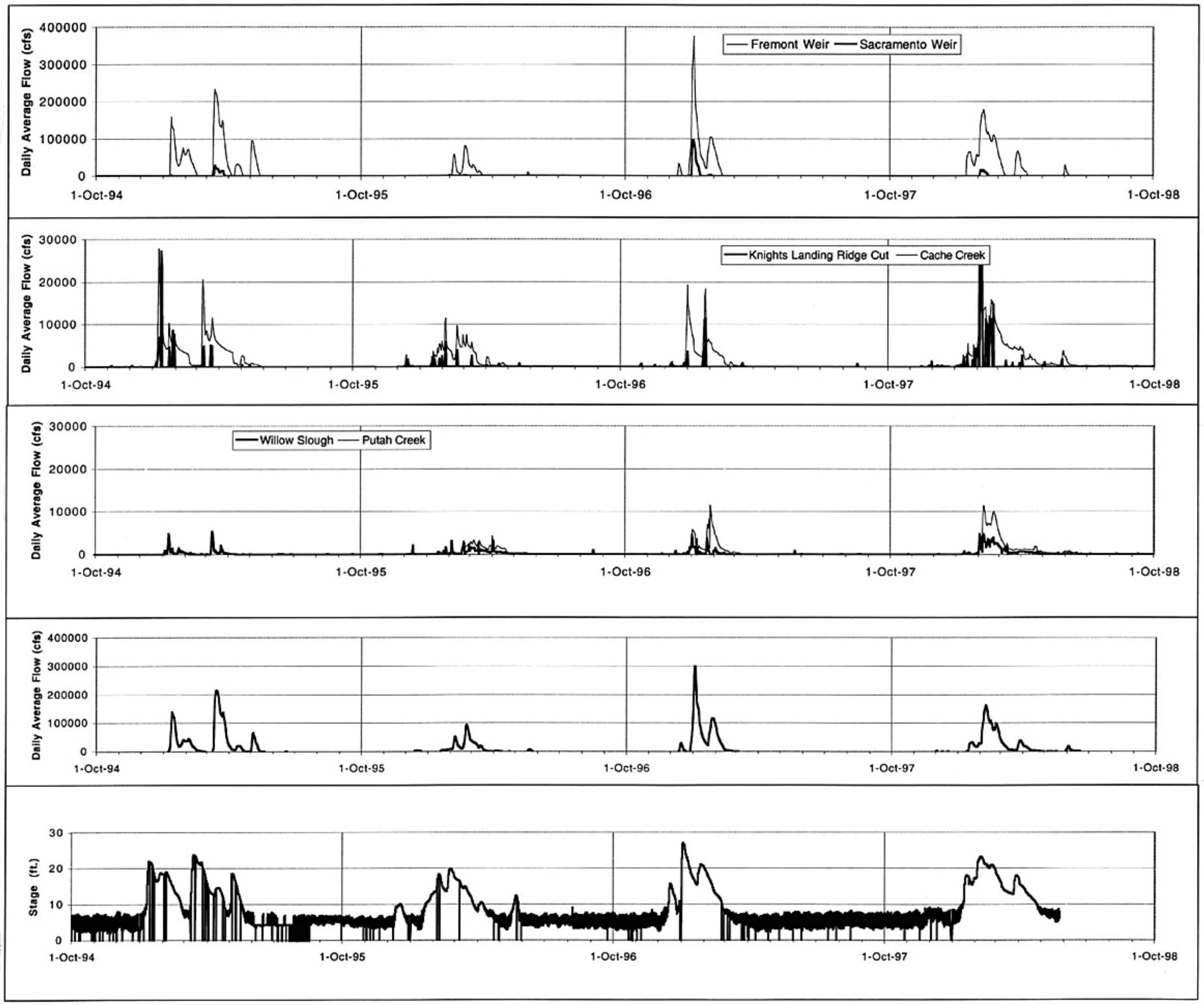
The examination of the Sacramento and Fremont Weir hydrographs reveal that Sacramento Weir is only active during periods when the Fremont Weir has been active. It also shows the Sacramento Weir flows are of a lesser magnitude and are shorter in duration than that of the Fremont. These relationships hold true for the entire period of record, revealing that the Sacramento Weir only contributes to the inundation already produced by Fremont Weir during large flood events.

The hydrographs reveal that Putah Creek tends to produce few high-flow events which are likely to occur in succession during wet years. This is likely due to the presence and operation of flows at the Monticello Dam (Lake Berryessa) and downstream at the Putah Diversion Dam (Lake Solano). Willow Slough is unregulated and produces a large number of small peak runoff events.

During dry periods when the weirs are not active, the four remaining tributaries have the potential to produce localized flooding within the Bypass. Exhibit 3.4-12 shows hydrographs of daily flows during a dry period from 1987 to 1990, when the weirs were not active (Yolo Basin Foundation 2001). The inputs from Putah Creek and Willow Slough were about 1,200 cfs and 1,500 cfs, respectively, in January 1985, while combined inputs from Cache Creek and Knights Landing Ridge Cut were approximately 5,000 cfs in January 1981 and January 1988. Putah Creek flows are often exceeded by Willow Slough inflows during small flood events when Lake Berryessa isn’t releasing.

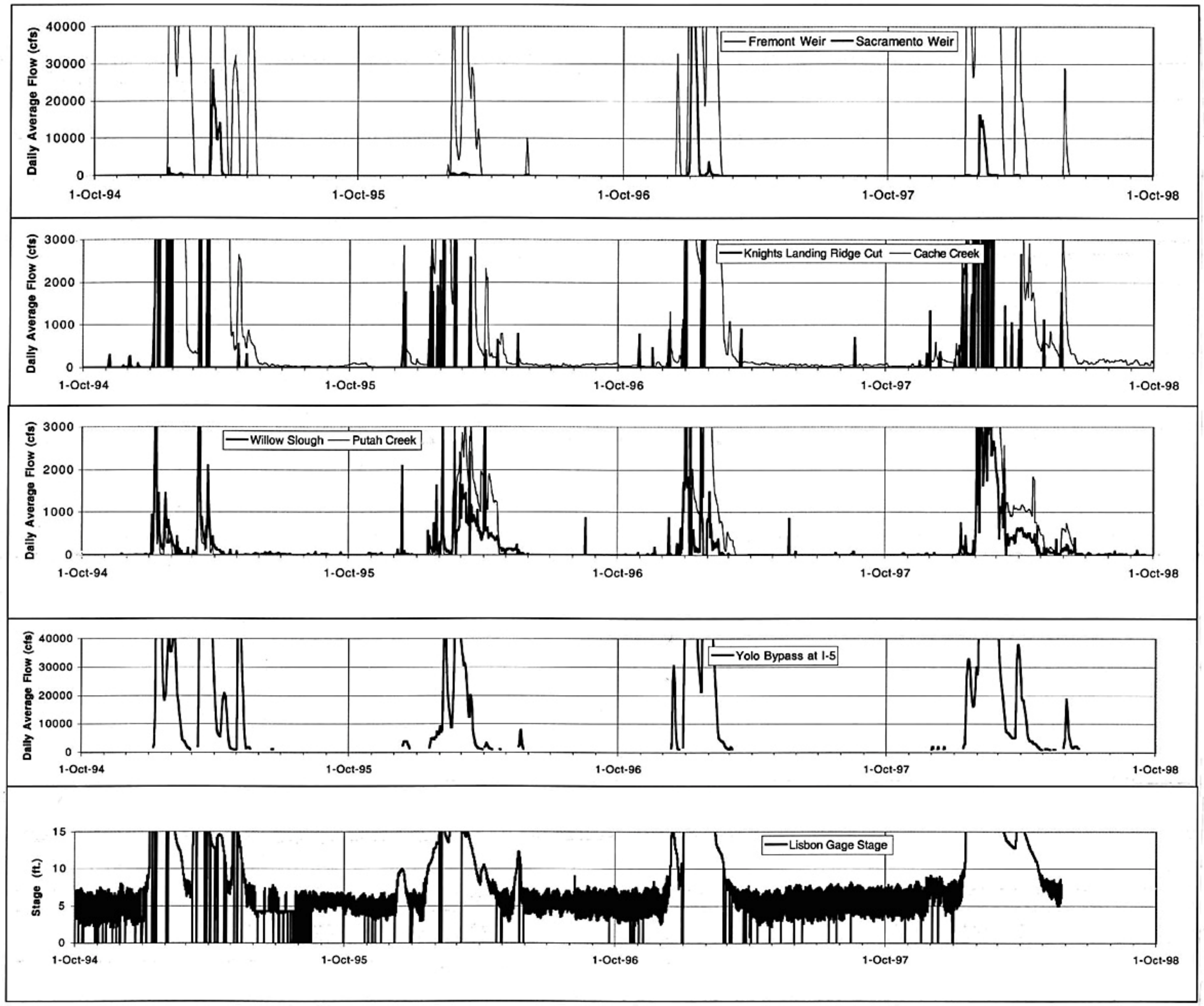
The tributaries were also examined for their contribution to localized flooding by comparing the increase in stage at the Lisbon gage to the magnitude of peak flows during dry periods when the weirs were not active. Daily discharge from Cache Creek are matched with hourly stage at the Lisbon Gage during the 1988 water year (weirs not active) as displayed in Exhibit 3.4-13. The peak events in December and January increased the stage at Lisbon by about 1.5 feet over its normal range. The importance of the tributaries on localized flooding is further demonstrated in Exhibit 3.4-14 which plots the increases in stage at the Lisbon Gage against peak flows on Cache Creek for similar events. For every 2,000 cfs of increased flow on Cache Creek, the stage at Lisbon increases approximately 1 foot (Yolo Basin Foundation 2001).

Local climatic conditions along with groundwater elevations can have implications on the extent of low flow inundation and creation of seasonal wetlands. Exhibit 3.4-15 displays the temperature, precipitation, and evapotranspiration regime from selected areas within the Yolo Basin. These data show that over the annual cycle, as temperature increases there is a corresponding increase in evapotranspiration and a decrease in precipitation.



Source: Yolo Basin Foundation 2001

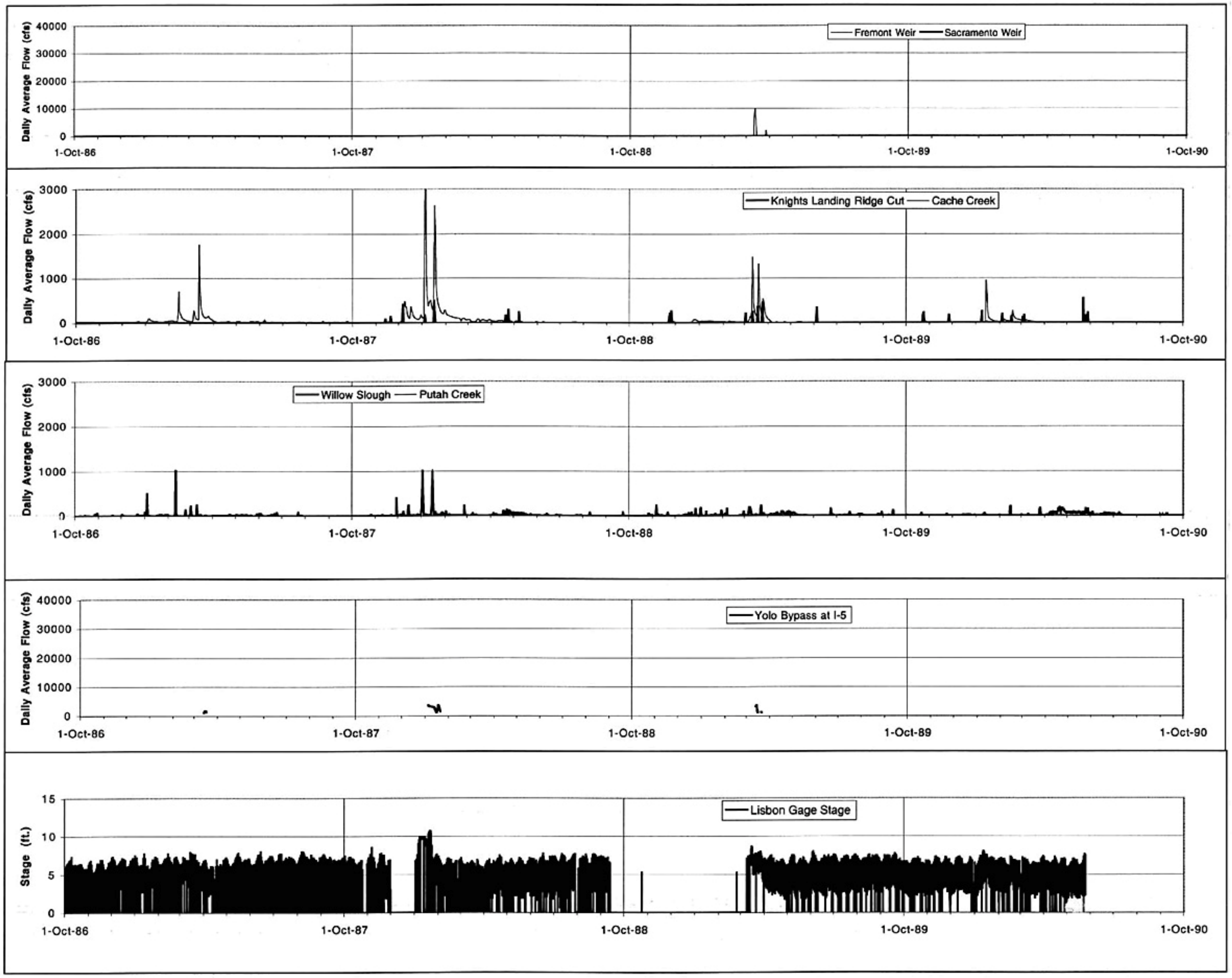
Hydrographs of Inputs to Yolo and Stage at Lisbon Gage 1995–1998 **Exhibit 3.4-10**



Source: Yolo Basin Foundation 2001

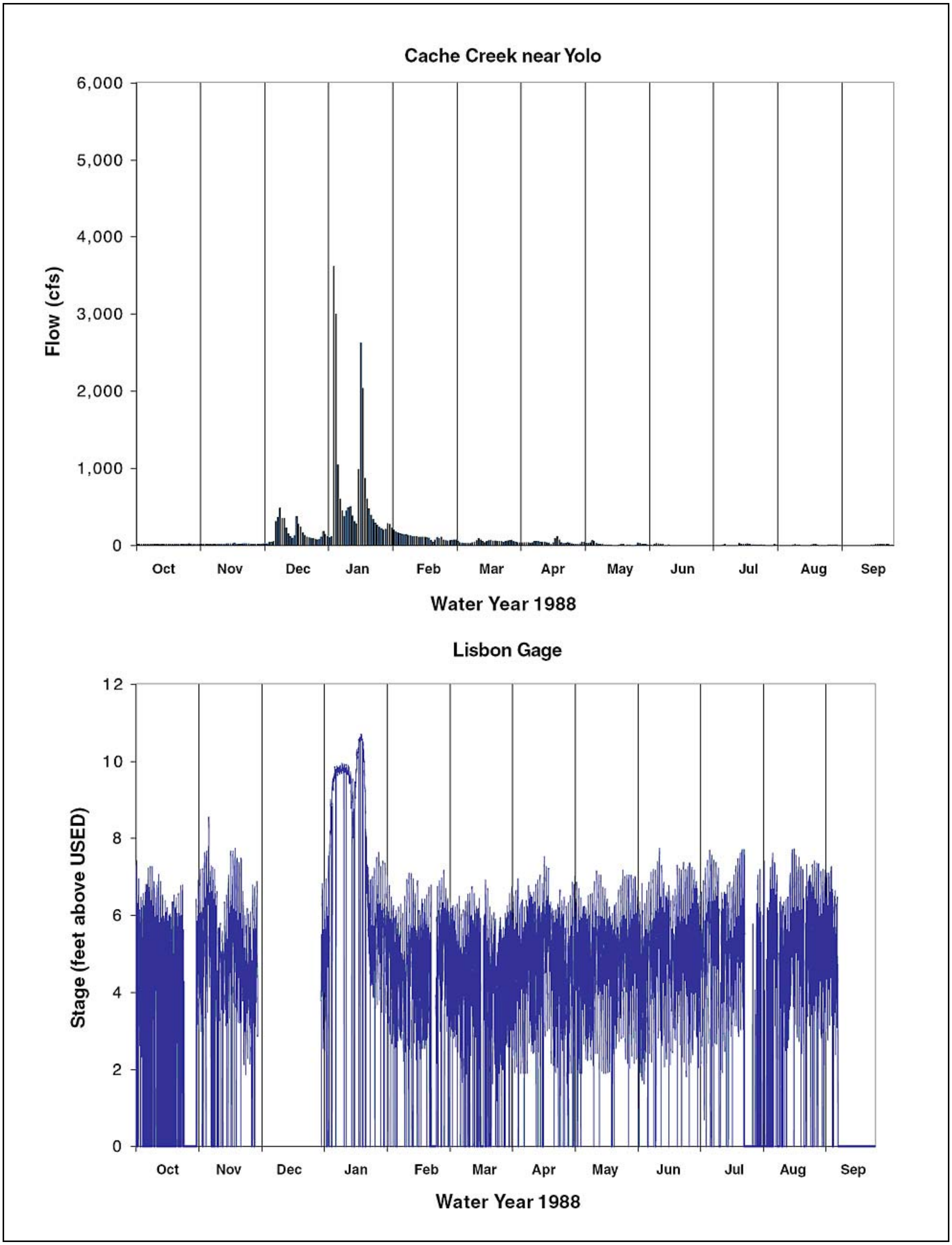
Hydrographs of Inputs to Yolo and Stage at Lisbon Gage 1995–1998
Expanded Scale

Exhibit 3.4-11



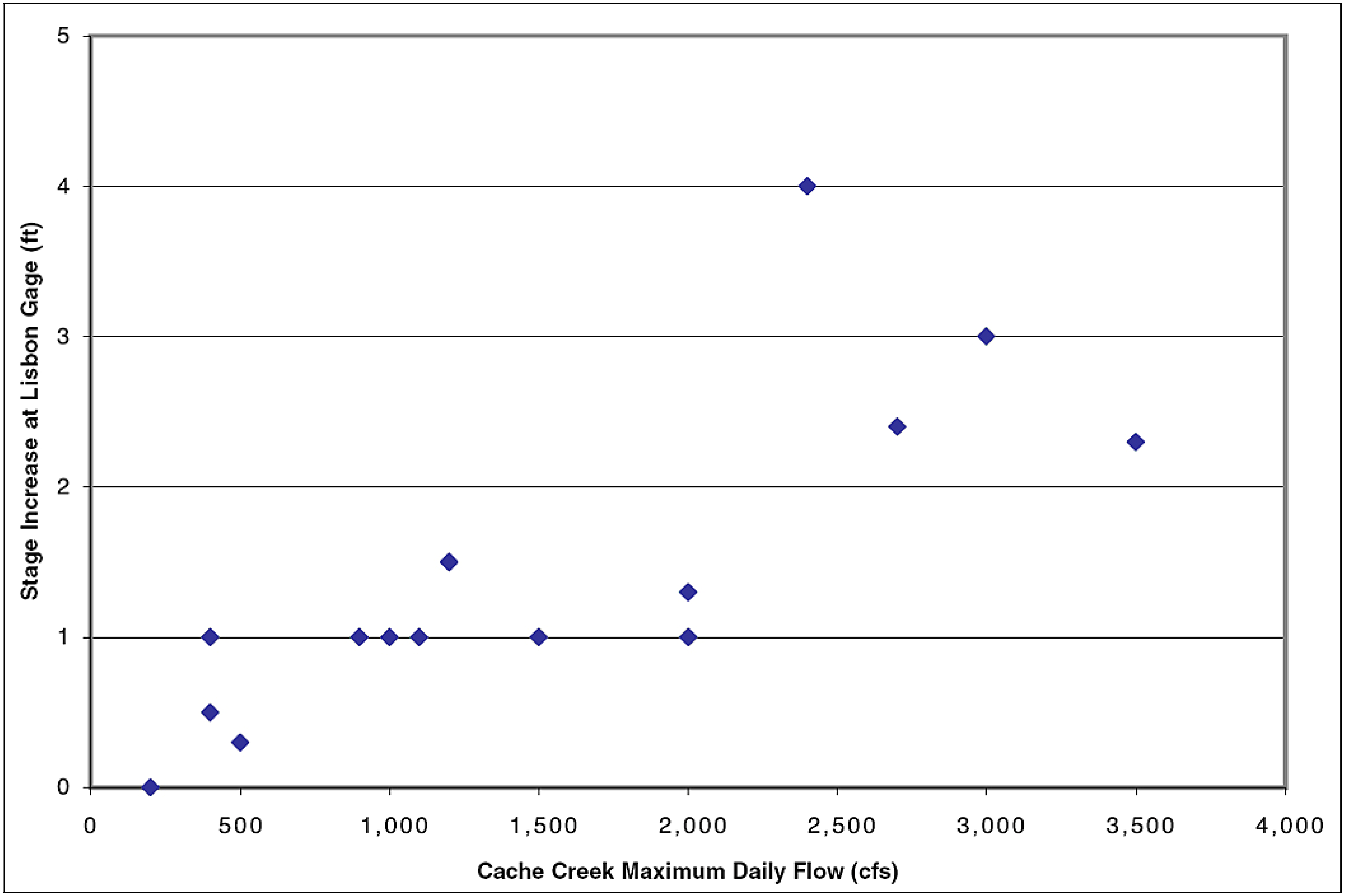
Source: Yolo Basin Foundation 2001

Hydrographs of Inputs to Yolo and Stage at Lisbon Gage 1987–1990 **Exhibit 3.4-12**



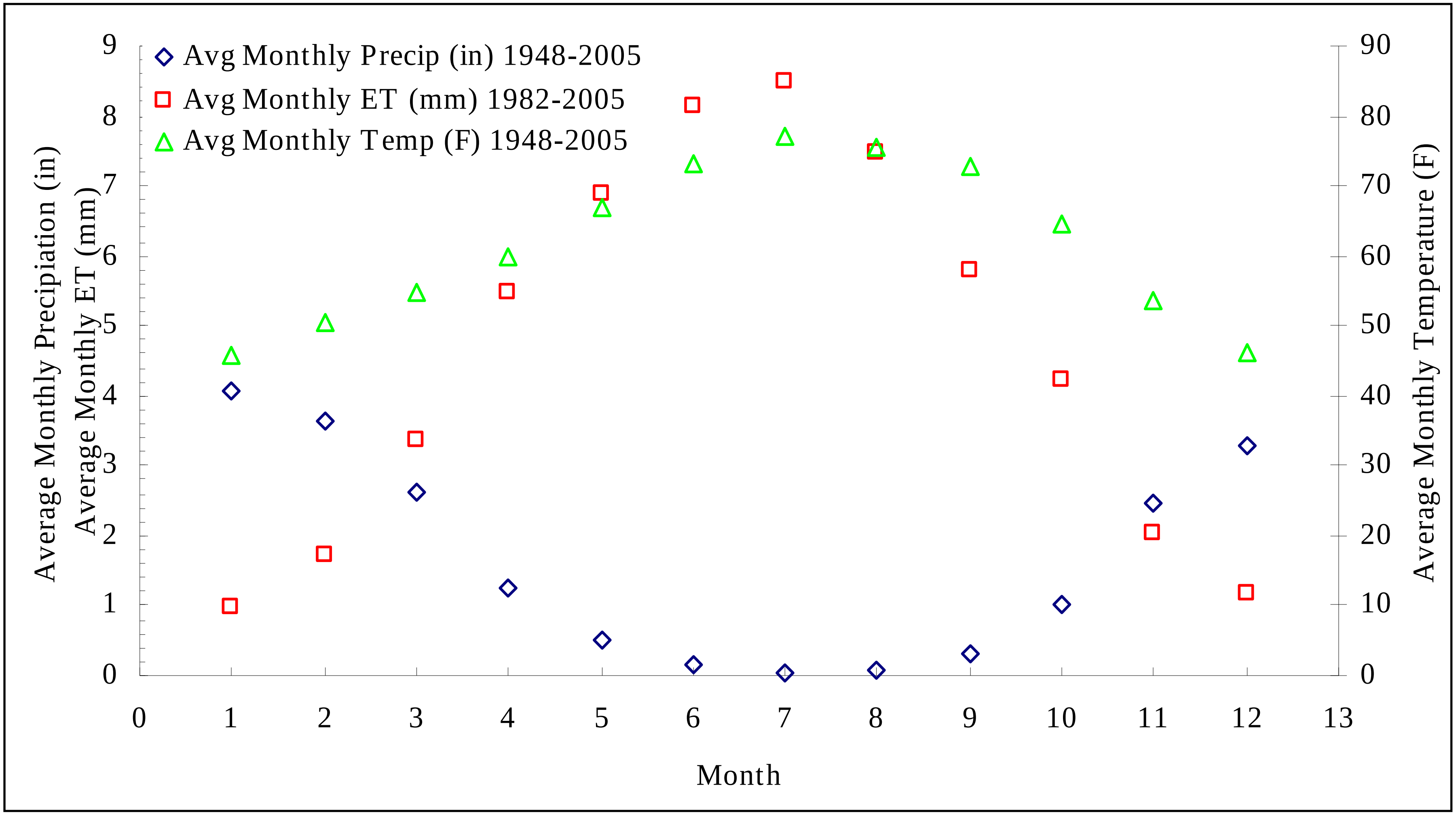
Source: Yolo Basin Foundation 2001

Cache Creek Flow and Lisbon Gage Stage 1988 **Exhibit 3.4-13**



Source: Yolo Basin Foundation 2001

Stage Increase at Lisbon vs. Cache Creek Maximum Daily Flow **Exhibit 3.4-14**



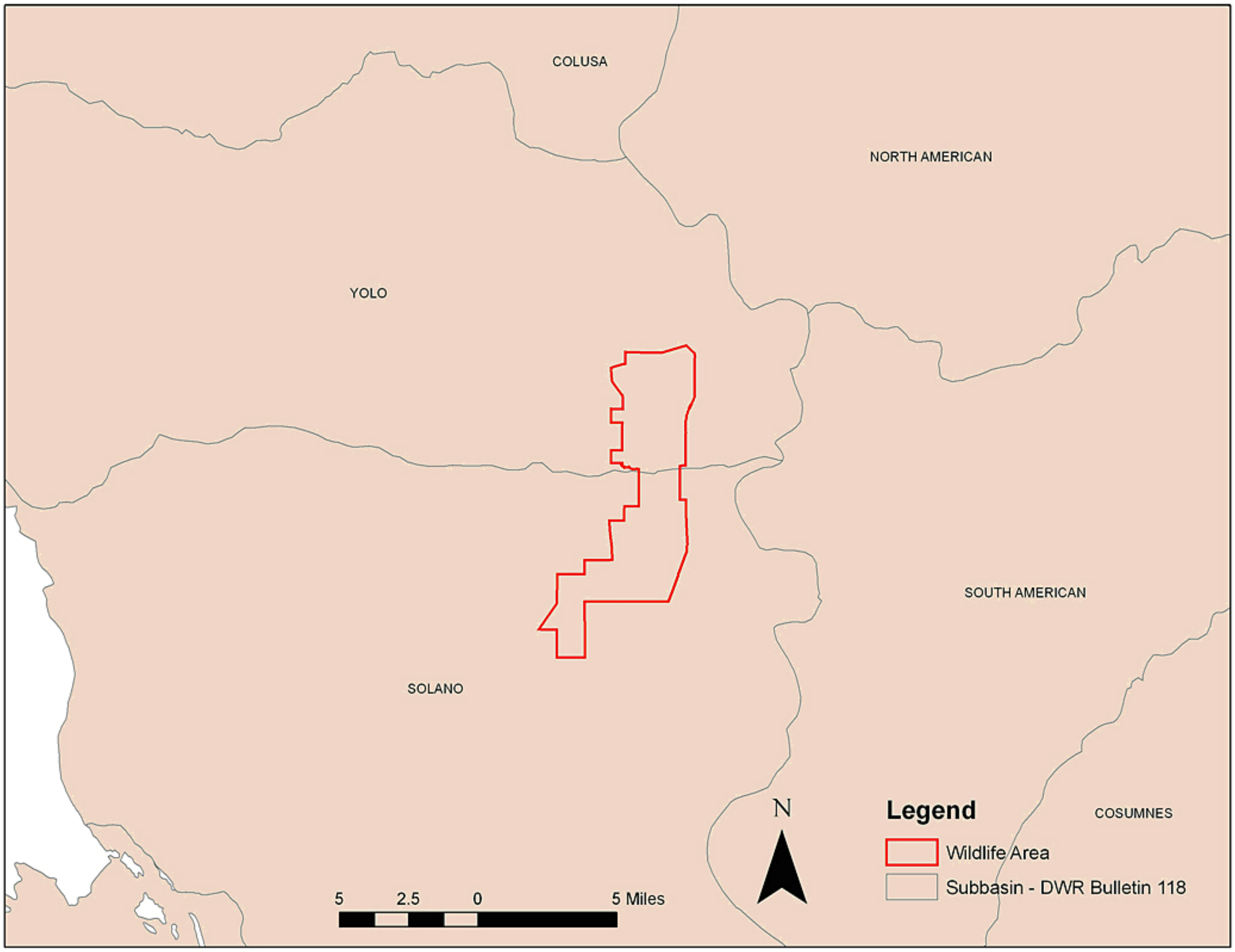
Source: PWA 2004

Average Monthly Evapotranspiration, Precipitation, and Temperature within the Yolo Basin

Exhibit 3.4-15

GROUNDWATER HYDROLOGY

The Yolo Bypass Wildlife Area is contained within the Sacramento Valley Groundwater Basin. Within this Groundwater Basin, the Yolo Bypass and Yolo Bypass Wildlife Area are located on the eastern edge of the Yolo and Solano Subbasins as mapped in DWR Groundwater Bulletin 118 as shown by Exhibit 3.4-16.



Source: DWR Groundwater Bulletin 118 2004

Groundwater Subbasins According to DWR Bulletin 118 **Exhibit 3.4-16**

Yolo Subbasin

The Yolo Subbasin is located primarily within Yolo County, bounded on the east by the Sacramento River, on the west by the Coast Range, on the north by Cache Creek, and on the south by Putah Creek. The Subbasin slopes gently from west to east with elevations ranging from 400 feet in the west to near sea level on the eastern edge.

The hydrogeologic formations relevant to the Yolo Bypass include flood basin deposits and recent stream channel deposits. The flood basin deposits consist of silts and clays and are generally between 100–150 feet thick with low permeability. The recent stream channel deposits consist of unconsolidated silt, fine- to medium-grained sand, gravel and cobbles (embedded in finer material) and are generally up to 150 feet thick with high permeability.

The channel deposits occur along the Sacramento River, Cache Creek, and Putah Creek and often lie above the saturated zone.

The subsurface flow within this Yolo Subbasin is obstructed from east to west by an anticlinal ridge oriented northwest to southeast. Subsurface outflow sometimes moves from the Yolo Subbasin into the Solano Subbasin to the south. Subsurface flow may also move beneath the Sacramento River to exchange with the South and North American River Subbasins.

Groundwater levels are impacted by periods of drought due to increased pumping and less surface water recharge, but recover quickly during wet years. Long term trends do not indicate any substantial decline, with the exception of localized pumping depressions in the vicinity of Davis, Woodland, and the Dunnigan/Zamora areas.

SOLANO SUBBASIN

The Solano Subbasin is bounded by Putah Creek to the north, the Sacramento River to the east, the North Mokelumne River to the southeast, and the San Joaquin River to the south. Elevations range from 120 feet in the northwest to sea level in the south.

The relevant hydrogeologic formations are similar to those of the Yolo Subbasin and occur along the Sacramento, Mokelumne and San Joaquin rivers and the upper reaches of Putah Creek. In the southern Delta region, the flood basin substrate contains a high proportion of peat, attesting to thousands of years of inundation. Over the past 150 years, as Delta islands have been drained and converted to agricultural use, the peat soils have subsided substantially.

The general subsurface flow direction is from northwest to southeast. Water level trends are similar to that of the Yolo Subbasin, but with large pumping depressions between Davis and Dixon.

3.4.3 WATER QUALITY

This section analyzes current water quality conditions in the Yolo Bypass Wildlife Area including the Yolo Bypass associated canals, Cache Creek, Willow Slough, Putah Creek and more generally in the greater Sacramento River drainage and Delta. Waters within and downstream of the Yolo Bypass Wildlife Area (i.e., Yolo Bypass) serve several beneficial uses, each of which has water quality requirements and concerns associated with it. These beneficial uses include habitat for fish and aquatic organisms, as well as a source of water for municipal, agricultural, recreational, and industrial uses. Water quality variables of particular concern in the Yolo Bypass are discussed in detail below.

GENERAL WATER QUALITY

Water quality in the Yolo Bypass, and more specifically the Yolo Bypass Wildlife Area, is influenced by a number of sources and processes. During flood events, water enters the Bypass from the Sacramento, Feather, and American rivers via the Fremont and Sacramento weirs. Other major inputs to the Bypass include, from north to south, the Knights Landing Ridge Cut (i.e., Colusa Basin Drain), Cache Creek, Willow Slough, and Putah Creek. Urban stormwater runoff and wastewater treatment facility discharges come from the University of California Davis campus and the cities of Davis and Woodland (City of Woodland 2005).

Basin Plan Beneficial Uses

Beneficial uses of water in the Yolo Bypass are legally designated by the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) in the Sacramento-San Joaquin River Basin Plan (Basin Plan) (Central Valley RWQCB 1998). Beneficial use designations determine the applicable water quality objectives. In addition to the beneficial uses for the Yolo Bypass, there are additional and different beneficial uses for the water bodies in and near the Bypass and/or Yolo Bypass Wildlife Area such as Cache Creek, Putah Creek, and the Delta. Consequently these additional beneficial uses are also considered. Between these water bodies, almost every beneficial use designation applies. The various beneficial uses include:

- Agricultural Supply,
- Water Contact Recreation,
- Non-contact Water Recreation,
- Warm Freshwater Habitat,
- Cold Freshwater Habitat,
- Spawning, and
- Wildlife Habitat.

An additional beneficial use, municipal and domestic supply does not apply to the Bypass but does apply to Cache Creek and Putah Creek upstream and to the Delta downstream.

Impaired Water Bodies

Under Section 303(d) of the Clean Water Act (CWA), states are required to develop lists of water bodies that would not attain water quality objectives after implementation of required levels of treatment by point source dischargers (municipalities and industries).

Section 303(d) requires that the state develop a total maximum daily load (TMDL) for each of the listed pollutants. The TMDL is the amount of loading that the water body can receive and still be in compliance with water quality objectives. The TMDL is also a plan to reduce loading of a specific pollutant from various sources to achieve compliance with water quality objectives. The TMDL prepared by the state must include an allocation of allowable loadings to point and nonpoint sources, with consideration of background loadings and a margin of safety. The TMDL must also include an analysis that shows the linkage between loading reductions and the attainment of water quality objectives. EPA must either approve a TMDL prepared by the state or disapprove the state’s TMDL and issue its own. After implementation of the TMDL, it is anticipated that the problems that led to placement of a given pollutant on the Section 303(d) list would be remediated.

The Yolo Bypass is not listed as impaired; however, TMDLs are in various stages of development and implementation for water bodies both upstream and downstream of the Yolo Bypass Wildlife Area (Table 3.4-3).

Sacramento River–Yolo Bypass and Associated Canals

Water quality of the Sacramento River is closely monitored to assess suitability for potable, agricultural, and wildlife/fisheries uses. Water quality of the Sacramento River, from Knights Landing to the Delta, was determined to be impaired by diazinon, mercury, and unknown toxins by the U.S. Environmental Protection Agency (USEPA) under Section 303(d) of the CWA (U.S. Environmental Protection Agency 2003). In 2003, the Central Valley RWQCB adopted a TMDL limit on discharges of diazinon to the Sacramento and Feather rivers (Central Valley RWQCB 2003). TMDLs for mercury and other toxins are currently under development. Pesticides from agricultural use are also contaminants of concern to water quality of the Sacramento River. Maximum concentration levels (MCLs) for pesticides such as thiobencarb and molinate have been developed by the Central Valley RWQCB (Yolo County Water Resources Assessment 2004).

To determine the effect of incoming discharges on water quality of floodwaters within the Yolo Bypass and the Sacramento River, the U.S. Geological Survey (USGS) conducted studies during 2000 and 2004–2005 (the 2004–2005 focused specifically on pesticides in water and sediment) (Schemel et al. 2002; Smalling et al. 2005).

Table 3.4-3
Clean Water Act Section 303(d) List of Impaired Waters Associated with the Yolo Bypass

Water Body	Pollutant / Stressor	Priority	Potential Source(s)	TMDL Status
Sacramento River (Red Bluff to Knights Landing)	Unknown toxicity	Low	Unknown	No activity
Sacramento River (Knights Landing to the Delta)	Diazinon[1]	High	Agriculture	Adopted
	Mercury	Medium	Resource extraction	No activity
	Unknown toxicity	Low	Unknown	No activity
Feather River (Lake Oroville Dam to Confluence with Sacramento River)	Diazinon[1]	High	Agriculture, Urban Runoff/Storm Sewers	Adopted
	Group A Pesticides	Low	Agriculture	No activity
	Mercury	Medium	Resource extraction	No activity
	Unknown toxicity	Low	Unknown	No activity
Colusa Basin Drain	Azinphos-methyl	Medium	Agriculture	No activity
	Carbofuran/Furadan	Low	Agriculture	No activity
	Diazinon	Medium	Agriculture	Adopted
	Group A Pesticides	Low	Agriculture	No activity
	Malathion	Low	Agriculture	No activity
	Methyl Parathion	Low	Agriculture	No activity
	Molinate/Odram	Low	Agriculture – irrigation tailwater	No activity
	Unknown Toxicity	Low	Agriculture	No activity
Cache Creek	Mercury	Medium	Resource extraction	2nd draft staff completed
	Unknown toxicity	Low	Unknown	No activity
Lower Putah Creek	Mercury	Low	Resource extraction	No activity
Delta (eastern portion)	Mercury	Medium	Resource extraction	Draft staff report complete
	Unknown toxicity	Low	Unknown	No activity
	Chlorpyrifos and Diazinon	High	Agriculture, Urban Runoff/Storm Sewers	Draft staff report in progress
	DDT	Low	Agriculture	No activity
	Group A pesticides	Low	Agriculture	No activity

[1] Recommended for delisting

Source: City of Woodland 2005; Central Valley RWQCB 2002

Sampling of physical and chemical parameters in 2000 during high flows where runoff from agricultural fields and tributaries were deposited to the Bypass concluded that, after initial draining of the floodplain after a large storm, the concentration of chemical contaminants within the Bypass is influenced directly by discharges from Cache Creek and the Knights Landing Ridge Cut. High concentrations of nutrients and contaminants, perhaps from abandoned mines and agricultural fields, were detected at discharge points from these sources. Spring rains flushed accumulated nutrients to the tidal area of the Sacramento River. The study recommended the addition of fresh water to perennial reaches of the Bypass to increase habitat quality for aquatic species (Schemel et al. 2002). The City of Woodland discharges its wastewater effluent to the Tule Canal, which flows to the Yolo Bypass.

Sampling conducted during 2004–2005 resulted in the detection of thirteen current-use pesticides in surface water samples collected during the study. The highest pesticide concentrations detected at the input sites to the Bypass corresponded to the first high-flow event of the year. The highest pesticide concentrations at the two sites sampled within the Bypass during the early spring were detected in mid-April following a major flood event as the water began to subside. The pesticides detected and their concentrations in the surface waters varied by site. The highest number of pesticides was detected in the suspended sediments compared with bed sediments and surface water. With the exception of a few compounds, the same pesticides were detected in the sediment and the water, and correlate with the agricultural use in each of the different watersheds. Measured pesticide concentrations varied by site/source watershed; however, Knights Landing Ridge Cut (i.e., Colusa Basin Drain) and Willow Slough generally appeared to have the highest concentration inputs into the Bypass (Smalling et al. 2005).

Cache Creek

Erosion and groundwater discharge from marine sediments have resulted in release of boron and mercury to the Cache Creek watershed. Mercury contamination from past mining activities, erosion of naturally occurring mercury latent soils, geothermal springs, and atmospheric deposition near Clear Lake and at tributaries to Cache Creek have contaminated sediments and water (Central Valley RWQCB 2004). Elevated quantities of mercury travel through the creek channel during high flows. Consequently, mercury has been detected in the Yolo Bypass. The Cache Creek watershed is a significant source of mercury in the Sacramento-San Joaquin Delta (Central Valley RWQCB 2004). The Central Valley RWQCB adopted a TMDL to limit discharges of mercury to Clear Lake and Cache Creek. A fish consumption advisory is in effect for Clear Lake fish to protect human health due to concerns of bioaccumulation of mercury in fish tissue (Office of Environmental Health Hazard Assessment 1994). Clear Lake is also listed as impaired by elevated levels of nutrients. Cache Creek is also impaired by unknown toxicity (U.S. Environmental Protection Agency 2003).

Boron concentrations typically range from 0.7 milligrams per liter (mg/L) in the spring to 2.2 mg/L in the winter, and the average concentration during the irrigation season is less than 1.0 mg/L (Yolo County Water Resources Assessment 2004).

Willow Slough

The Yolo County RCD is initiating a program to monitor suspended sediment, nutrient, and water level at 4–6 sites along Willow Slough. Previous monitoring studies conducted by the County Department of Health Services and UCD noted invertebrate and algae impairment from unknown causes and sources. The City of Davis discharges its treated wastewater effluent to Willow Slough Bypass. The Central Valley RWQCB requires municipal dischargers such as the City of Davis to regularly perform effluent and receiving water toxicity testing for invertebrates and algae. Pesticide concentrations in Willow Slough waters have been measured to be above other Bypass tributary water bodies (Smalling et al. 2005).

Putah Creek

Much like the Cache Creek watershed, the Putah Creek watershed contains high concentrations of mercury and boron. During low flows in summer months, Putah Creek flow is dominated by effluent downstream of UCD wastewater treatment plant outfall. Lower Putah Creek, downstream of Lake Solano, is listed as impaired by mercury (originating from old mines in the upper watershed) on the US EPA 303(d) list (U.S. Environmental Protection Agency 2003). Water temperature monitoring by UCD documented seasonal warming profiles downstream of the Putah Diversion Dam (PDD), diurnal temperature fluctuations, and localized thermal stratification (Yolo County Water Resources Assessment 2004). Pesticide concentrations in Putah Creek were generally low relative to other sites in the 2004–2005 study. The only exception was concentrations measured in bed sediments, which were higher than at most other locations (Smalling et al. 2005).

Knights Landing Ridge Cut (Colusa Basin Drain)

The Colusa Basin Drain (Drain) watershed comprises nearly 1,620 square miles in the Sacramento Valley, and includes portions of Glenn, Colusa, and Yolo counties. There are 32 ephemeral streams that convey storm runoff to the Drain. The Drain is an artificial channel designed to convey irrigation drainage to the Knights Landing outfall gates for discharge into the Sacramento River. When the water level in the river exceeds the water level in the Drain, Drain water discharges into the Knights Landing Ridge Cut directly into the Yolo Bypass. The Knights Landing Ridge Cut, which consists of two excavated channels with a center island, has a discharge capacity of approximately 20,000 cfs. Water from the Drain is pumped into the Ridge Cut for irrigation at other times of the year, providing additional water into the upper Bypass during the summer-fall period. The Drain is listed as a water quality impaired water body due to a number of agricultural pesticide-related pollutants (Table 3.4-3) (Central Valley RWQCB 2002). Pesticide concentrations (in the 2004–2005 study) in Drain water were high relative to all other sample sites (Smalling et al. 2005), consistent with the impairment listing status noted above.

As discussed in Section 3.1 above, proposals have been developed to divert additional water from the Drain into the Yolo Bypass on a more continuous year-round basis. This potential project could have water quality implications for the Yolo Bypass Wildlife Area.

Groundwater Quality

Groundwater in the Yolo Basin is characterized by the presence of sodium magnesium, calcium magnesium, and/or magnesium bicarbonate. The groundwater quality is characterized as good for agricultural and municipal uses, although it is hard to very hard overall. Elevated concentrations of selenium, nitrate, and boron have been detected in groundwater along Cache Creek and the Cache Creek Settling Basin area. Brackish and saline waters are found in water bearing units underlying the Tehama Formation (California Department of Water Resources 2004). According to monitoring conducted in the Yolo Subbasin beneath the City of Davis and University of California, average concentrations of arsenic in the Tehama formation below 600 feet below ground surface are 0.04 mg/L (Yolo County Water Resources Assessment 2004.) This value exceeds the USEPA MCL of 0.01 mg/L that became effective as of January 23, 2006 (U.S. Environmental Protection Agency 2005). The existing California MCL for arsenic is 0.05 mg/L, as stated in the California Code of Regulations (Section 64431 - Maximum Contaminant Levels-Inorganic Chemicals).

POLLUTANTS OF CONCERN

Larry Walker Associates completed an evaluation of water quality conditions as a component of a water quality management plan for the Yolo Bypass (City of Woodland 2005). This plan included identification of pollutants of concern (POC) for the Bypass. POCs identified in the plan are consistent with many of those identified in the discussions above.

Yolo Bypass Water Quality Management Plan

The objective of the project was to develop a comprehensive water quality management plan for the Bypass. The general steps followed to develop the plan were to (City of Woodland 2005):

- Identify through review of existing information and stakeholder input current POCs for the Bypass;

- Conduct surface water quality monitoring to help quantify POCs and their major sources;
- Identify and evaluate effective, implementable control measures for reducing POC concentrations and loads;
- Investigate, if necessary, the applicability of current water quality criteria for the POCs and the feasibility of developing site-specific objectives (SSOs);
- Involve stakeholders regarding POCs and potential control measures; and
- Produce a Water Quality Management Plan containing a recommended implementation program to address POCs that are degrading surface water quality.

The POCs were identified by stakeholders after a cursory review of available data. The identified POCs were then monitored over a one-year period. Based on these monitoring results and stakeholder input, the POCs were prioritized as shown in Table 3.4-4.

Table 3.4-4
Yolo Bypass Water Quality Management Plan Pollutants of Concern

Pollutant of Concern	Priority		
	High	Medium	Low
Bacteria Total coliform Fecal coliform E. coli	X		
Boron	X		
Metals			
Aluminum	X		
Chromium			X
Copper			X
Lead			X
Mercury	X		
Selenium			X
Nitrate			X
Organic Carbon Total organic carbon Dissolved organic carbon		X	
Pesticides and Herbicides			
OCs (DDE and DDT)		X	
OPs (Chlorpyrifos and Diazinon)		X	
Carbamates (Diuron and Methomyl)			X
Salinity	X		
Total Suspended Solids (TSS)			X

Source: City of Woodland 2005

The discussion below focuses on high priority pollutants of concern identified in the water quality management plan that are also concerns related to management at the Yolo Bypass Wildlife Area.

Mercury

One water quality variable of particular concern regarding management activities at the Yolo Bypass Wildlife Area is methylmercury. Mercury occurs as a result of both natural and anthropogenic sources in the environment and continually cycles in the aquatic environments of the Sacramento River and San Joaquin River basins and Delta. The cycle involves different chemical forms and/or species of mercury as a result of both chemical and biological reactions in aerobic and anoxic microenvironments. On a world wide scale, mining sources are geographically localized and generally small but, in California's Central Valley, they are of great importance (Jones and Slotten 1996).

Historic gold-mining practices created the primary source of mercury in northern California rivers and the Delta. The mountain ranges that surround California's Central Valley and drain into the Sacramento and San Joaquin watersheds contain extensive mineral deposits. Discovery of gold deposits in the Sierra Nevada stimulated the California Gold Rush in 1848, and an abundance of mercury from hundreds of mercury mines in the Coast Ranges facilitated the rapid historic proliferation of gold-mining operations that used the mercury-amalgamation process to extract gold (Alpers and Hunerlach 2000). Hundreds of hydraulic gold-placer mines operated on the east side of the Central Valley (e.g., Feather River watershed). About 100,000 metric tons of mercury was produced by mercury-mining operations in the Coast Ranges, and about 12,000 metric tons of this were used in gold mining in California, with annual losses at mine sites ranging from about 10 to 30 percent of the mercury used (Alpers and Hunerlach 2000). Mercury mines in the Cache Creek and Putah Creek watersheds (both upstream of the Yolo Bypass) supplied much of the mercury amalgam for gold mining in the Sierras and other industrial uses. The majority of Coast Range mercury mines that supplied this practice has since been abandoned and remains unreclaimed. As a result of these two activities, bulk mercury contamination exists today on both sides of the Central Valley (Jones and Slotten 1996) and within the Yolo Bypass. A large proportion of the loads of mercury and methyl mercury in San Francisco Bay and the Delta are thought to originate in Cache Creek and pass through the Yolo Bypass (Domagalski et al. 2002).

Methylation of mercury is the key step in the entrance of mercury into the food web. Nearly 100% of the mercury that bioaccumulates in fish tissue is methylated. The rates of methylation are influenced by the bioavailability of inorganic mercury to methylating bacteria, the concentration and form of inorganic mercury, and the distribution and activity of methylating (i.e., sulfate-reducing) bacteria (Jones and Slotten 1996; Heim et al. 2003). Solid phase methylmercury concentrations vary seasonally; with the highest concentrations tending to occur during late spring and summer (Heim et al. 2003).

Gill et al. (2002) found that sediments appear to be a net source of methylmercury into the water column. Sinks or losses of total mercury and methylmercury include volatilization, sequestration (i.e., storage) in local soil, and biological uptake (i.e., accumulation in organisms' tissues). Demethylation of methylmercury is considered likely to be the major loss mechanism for this form. Stephenson et al. (2002), who employed a mass balance approach, suggests that the Delta is a sink for methyl mercury, due to photodemethylation (i.e., process of demethylation of mercury through sunlight exposure) or storage via bioaccumulation. Slotton et al. (2003) suggests that inorganic mercury newly delivered from upstream sources is more readily methylated and bioaccumulated than is inorganic mercury stored in the Delta and lower tributaries.

Wetlands support methylation processes and may export methylmercury to surrounding channels (Heim et al. 2003), however, recent research shows that there is still much to learn about methylmercury production and export processes from wetlands. Recent studies in the Delta indicate that some wetlands import and some export methylmercury (Stephenson, pers. comm., 2006). Two almost identical wetlands on Twichell Island that differ in depth and channel structure produce very different amounts of methylmercury (Stephenson, pers. comm., 2006). Biological findings indicate no distinct localized increase in net methylmercury bioaccumulation in wetlands versus adjacent upland areas within Delta subregions (Slotten et al. 2003). Some of the most well developed, highly vegetated wetland tracts have exhibited reduced levels of localized net mercury bioaccumulation (Slotten et al. 2003). Recent DFG studies indicate that permanent wetlands could serve as demethylation ponds for water draining from seasonal wetlands, where methyl mercury levels are increased (Stephenson, pers. comm., 2008).

Additionally, recent findings on methylmercury production rates suggest that there may be an inverse relationship between environmental conditions that support high concentrations of biologically available mercury (e.g., relatively clean inorganic sediments [typically not associated with wetlands]) and those that support high sulfate reduction rates (e.g., oxic-anoxic sediment interface with relatively high amounts of organic material [typically associated with wetlands]) (Marvin-DiPasquale, pers. comm., 2005). These results suggest that wetland restoration may result in localized mercury bioaccumulation at levels similar to, but not necessarily greater than, levels within their surrounding subregion.

Mercury research from the Delta and tributaries consistently indicates that sediment methylmercury concentrations, methylmercury formation and demethylation, organism uptake and bioaccumulation, and mass flux of methylmercury transfer from sediment to water are highly dynamic processes that can vary considerably, depending on the land use/community type (e.g., wetlands/marsh, agriculture, open water), location in the region, and a host of other factors (e.g., hydrologic factors, salinity, pH, temperature, organic matter, temporal-seasonal conditions) (Jones and Slotten 1996, Foe 2002, Gill et al. 2002, Stephenson et al. 2002, Choe and Gill 2003, Choe et al. 2003, Davis et al. 2003, Foe et al. 2003, Heim et al. 2003, Slotten et al. 2003, Wiener et al. 2003).

As discussed in Section 3.1.4, the Central Valley Regional Water Quality Control Board is developing a Total Maximum Daily Load (TMDL) for methyl and total mercury in the Sacramento-San Joaquin Delta. This action could affect the management of the Yolo Bypass Wildlife Area.

Toxic Chemicals

Toxic chemicals including pesticides have impaired water quality in many Central Valley and Delta waterways and have recently been studied in the Yolo Bypass (Smalling et al. 2005). High concentrations of some metals from point and nonpoint sources appear to be ubiquitous in these waterways. In addition to mercury (discussed above), high levels of other metals (i.e., aluminum, copper, cadmium, and lead) in Central Valley and Delta waters are also of concern. Additionally, in localized areas of the Delta, fish tissues contain elevated levels of dioxin as a result of industrial discharges (State Water Resources Control Board 1999).

As discussed above, pesticides are found throughout the waters and bottom sediments of the Bypass. The more persistent organochlorine pesticides (e.g., DDT) are generally found throughout the system at higher levels than the less persistent organophosphate compounds (e.g., diazinon). Pesticides have concentrated in aquatic life in the Delta, and the long-term effects are unknown. The effects of intermittent exposure of toxic pesticide levels in water and of long-term exposure to these compounds and combinations of them are likewise unknown (State Water Resources Control Board 1999).

Salinity

High salts content in water potentially impacts productivity of agricultural crops and may create problems for seasonal wetlands. Local groundwater aquifers are relatively high in salts content (City of Woodland 2005). Because the Yolo Bypass Wildlife Area relies primarily on surface water for irrigation and flooding, high salt content groundwater is not as much of a concern. Prior to the construction of Shasta Dam, salinity was indeed more of an issue in the Yolo Basin with saline conditions being reported in the vicinity of County Road 155.

Bacteria

The bacteriological quality of Bypass waters, as measured by the presence of coliform bacteria, varies depending upon the proximity of waste discharges and land runoff. Bacteria are not a primary water quality concern at the Yolo Bypass Wildlife Area.

Selenium

Varying concentrations of selenium have been found naturally occurring in soils in California's Central Valley and can be found in high concentrations in agricultural drain water. The two primary agricultural drains discharging to the Yolo Bypass, Knights Landing Ridge Cut and Willow Slough Bypass, have been measured to have relatively high total and dissolved selenium concentrations and have been identified as low priority pollutants of concern (see Table 3.4-4) (City of Woodland 2005). The City of Davis conducts ongoing food chain and avian egg monitoring for selenium bioaccumulation. No adverse effects have been detected during the last 7 years of monitoring (City of Davis, unpublished data) Some of the effects on organisms when selenium is present in aquatic environments are reproductive dysfunction, deformities, anemia, and death in many species of birds, fish, and mammals (Amweg et al. 2003).

Boron

Boron is an essential element for plant growth and is needed in relatively small amounts; however, if present in amounts appreciably greater than needed, it can become toxic. Boron toxicity can affect nearly all crops and vegetation types but, like salinity, there is a wide range of tolerance among crops (City of Woodland 2005). Currently, boron is not of primary concern to agricultural and/or wetland management at the Yolo Bypass Wildlife Area. However, boron concentrations do have the potential to effect management if concentrations increase.

A reconnaissance investigation (Setmire et al. 1990) conducted at the Salton Sea under the Department of the Interior's National Irrigation Water Quality Program (NIWQP) identified boron as a contaminant of concern for wildlife. A more detailed study, conducted as a follow-up found that ruddy duck liver concentrations of boron increased during the course of their winter stay at the Salton Sea (Setmire et al. 1993). Additionally, laboratory studies with mallards indicate that reproductive impacts can occur at dietary concentrations of boron that have been found in waterfowl food items in the San Joaquin Valley (Smith and Anders 1989).